TO

MRS. JOHN GREGORY,

MILWAUKIE, WISCONSIN.

My Dear Lizzie:—

I do not know any one to whom the following pages will prove more attractive than to yourself.

Cradled, as you literally were in the midst of Microscopes; surrounded by, and throughout your early life accustomed to examine preparations of all sizes and kinds, and frequently to hear descriptions of them in the public lecture room, this volume, with its illustrations, must needs possess greater charms for you than for most readers.

You will be constantly reminded, when gazing on the pictorial representations of well-remembered preparations, of the many delightful hours we have spent together in days that are past, enraptured with the surpassing beauty of the originals!

But, under any circumstances, as a record of the labors of my life, I cannot but think it will ever be acceptable to you; moreover, I venture to hope it will be found of some value in your family, by contributing to the education of your own children.

It is a subject of deep regret to me, that I have been deprived of your judicious, keen criticism; but, with all its faults, I dedicate this book to you, as the least testimonial I can offer of a Father's fond affection.

That you may long enjoy every earthly blessing, is the sincere and heartfelt wish of,

My Dear Child,

THE AUTHOR.

PREFACE.

The Author having been appointed to the Chairs of Vegetable and Animal Physiology and Entomology, in the State Agricultural College of Michigan, has felt the want of a suitable text-book, for the use of his students, and not being aware of any existing work on the plan he considers essential for the acquisition of these subjects, he has prepared the accompanying volume to aid him in his labors, and to fulfil a request, previously made to him by the Superintendent of Public Instruction of the State of Michigan, the Hon. Ira Mayhew, to write such a work.

The "Botanies" hitherto published, are insufficient as physiologies; and the Animal physiologies, as yet prepared "for the use of Schools," are simply epitomized treatises on Human anatomy, and are generally too technical and obscure to be available for the purposes of popular instruction.

This latter subject, a distasteful one, even to Medical Students, who rarely learn it, must necessarily prove a severe tax to the youth of both sexes, who throng the public and private schools of the country, whilst many of the illustrations supposed to be necessary to these books, are, to say the least of them, most uninviting.

The attempt to teach only Human Physiology, like a similar proceeding in regard to anatomy, can only end in failure: whereas, if the origin (so to speak) of the organic structures in the animal kingdom, be sought for and steadily pursued through all the classes, showing their gradual complication, and the necessity for the addition of accessory organs, till they reach their utmost development and cul-

minate in man, the study may (possibly) be rendered an agreeable and interesting one, and be fruitful in profitable results.

Throughout the accompanying pages, this principle has been kept steadily in view, and it has been deemed of more importance to impart solid and thorough instruction on the few subjects discussed, rather than embrace the whole field of physiology, and, for want of space, fail to do justice to any part of it.

The development of the nutrimental organs, and of the brain and nervous system, have been considered as of primary importance, and to the consideration of these topics much space and great care have been devoted. The latter subject has always been most difficult to understand, and the attempt has been made by the Author, to popularize this very abstruse subject; with what success remains to be seen.

In proof that the views above-enunciated are supported by high authority, the opinions of the distinguished Haller, and the late Baron Cuvier, are quoted; moreover, the Authors of the best and most reliable treatise on human physiology—Todd and Bowman—have adopted, and given expression to the same opinion.

"A knowledge of human anatomy alone, is not sufficient to enable us to form accurate views of the functions of the various organs." Before an exact knowledge can be formed of the functions of most parts of living bodies, Haller says, that "the construction of the same part must be examined and compared in man, in various quadrupeds, in birds, in fishes, and even in insects."

Cuvier has compared the examination of the comparative anatomy of an organ in its gradation from its most complex to its simplest state, to an experiment which consists in removing successive portions of the organ, with a view to determine its most essential and important part. In the animal series we see this experiment performed by the hand of nature, without those disturbances which mechanical violence must inevitably produce. Thus we learn that one portion of the nervous system, in those animals in which it has a defi-

nite arrangement, is pre-eminently associated with the mental principle, and is connected with, and presides over, the other parts.

The brain is always situated at the anterior or cephalic extremity of the animal, and with it are invariably connected the organs of the senses, the inlets to perception. We soon find that the brain exhibits a subdivision into distinct parts; and of the relative importance of these parts, and their connection with the organs of sense, and with the intellectual functions, we derive the most important information, from the study of comparative anatomy.

In place of "questions," the Author has preferred to give an analysis of the paragraphs, which will render it equally compulsory with the Teachers and the students, to make themselves acquainted with the book; moreover, it forms an *analytical index* of the contents of the lessons, of much value.

Instead of appending a *glossary of technical terms*, necessarily used, the translation of difficult, or uncommon words has been given, simultaneously with the use of them, and to this rule, it is hoped, there are but few exceptions.

It is presumed that the beauty of the wood engravings, that so plentifully adorn this work, is so apparent, that little requires to be said in their praise; the Author feels, however, desirous of expressing his deep obligations, and tendering his best thanks to the accomplished artist who produced them, Mr. H. E. Downer, of this City. As the work of a young man *only nineteen years of age*, they are extraordinary; whilst the incessant labor necessary to their production, and the untiring energy and zeal displayed by him, are worthy of the utmost commendation. It may be a matter of observation and remark, that the *style* of all the engravings is peculiar. Nearly thirty years ago, the Author had a series of 400 diagrams, for public lectures, prepared on this principle—white figures, on a dead-black ground. They consisted of subjects kindred to the illustrations of this book, and, from their distinctness, elicited universal approbation.

He has always (subsequently) thought that the same plan would prove most effective for wood-engravings of the same

tissues and structures, and this opinion induced him to make the experiment: how far it is successful, he leaves others to determine. He ventures to presume that, in the delineation of *nerves*, there can be no doubt, as they are always *eminently white;* and such is their extreme delicacy in the lower animals, that justice could not be done to them by the adoption of any other method.

In the list of engravings, the word "Original" very frequently occurs; it is not intended to imply that such illustrations have not been published before, but simply to indicate that the drawings have been made from preparations dissected by the Author, and to be found, either in the Museum of the Royal College of Surgeons, or forming a portion of his private collection. He is quite aware, however, that a great proportion of them are not only original, but unique, and have not been published before.

Finally, should the perusal of this book impart to its readers only a tithe of the pleasure the Author has had in its production, they and he will be alike repaid.

DETROIT, MICHIGAN, *February*, 1858.

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PART I.

VEGETABLE PHYSIOLOGY.

LESSON I.

INTRODUCTION.

1. Physiology, or the science which teaches the functions of all the different parts or organs of animals and plants; or the offices which they perform in the economy of the individual; or, in other words, the *science of life*, is daily esteemed of greater importance.

2. Physiology, as now understood, has become quite a modern science, and one that owes its great advancement and chief excellence to the Microscope alone.

3. Without its invaluable aid, our notions and opinions would be as crude, unsatisfactory, and erroneous, as were those of our forefathers. Before its mighty presence every fragment of a tissue is bound to succumb; it has no preconceived theory to support; it is called upon to do but one thing to assist us in our researches, and nobly it does it!—*it tells the truth*, whereby the laws of physiological science are rendered as certain as a problem in Mathematics.

4. The Microscope has originated a new science—Histology—from two Greek words, which signify a "discourse on tissues;" now what is a tissue? Webster's definition is as follows: "*in anatomy*, texture or organization of parts. The peculiar, intimate structure of a part is called its *tissue*. A part of a fibrous structure is called a *fibrous tissue*. The organs of the body are made up of simpler elements, some generally diffused through the body, and others peculiar to particular organs. These simpler structures are called the *tissues* of the body; as, the cellular *tissue*, the mucous *tissue*, &c."

5. Since the invention and constitution of Histology, *as a science*, Physiology has made enormous strides.

6. A knowledge of the intimate structure of the tissues, as well of vegetables as of animals, has been of the greatest value to the physiologist. Had the important theory of development by cells not been discovered by Schawn and Schleiden in plants, the like processes had remained unknown as the true principle of development of the inferior animals, of the development of the Ovum in the higher mammalia, and as the plan by which the human family is continued.

7. There can be no accurate knowledge of Physiology, save that which is based upon an intimate acquaintance with the ultimate microscopical structure of *all* tissues; this cannot be learned from books, at the present time, simply because no sufficiently illustrated and voluminous work on this subject has yet been published; under the best circumstances, it appears to be most desirable to learn by the actual examination of the structures themselves.

8. It is quite true that it requires a lifetime to acquire the skill to prepare such illustrations, but the devotion necessary to become accomplished as a physiologist, is certainly not greater than the requirements of Chemistry, Botany, or any other science, or greater than is necessary to qualify a man for the legal or other learned professions.

9. The simple cellular plants offer illustrations of the lowest organized forms we are acquainted with. In them we find that a *single cell* constitutes the entire plant.

10. This cell is produced from its germ, assimilates nutriment, converts a portion of it into the substance of its own cell-wall, secretes a nucleus within its cavity, and ultimately produces a reproductive germ, that is to continue the race.

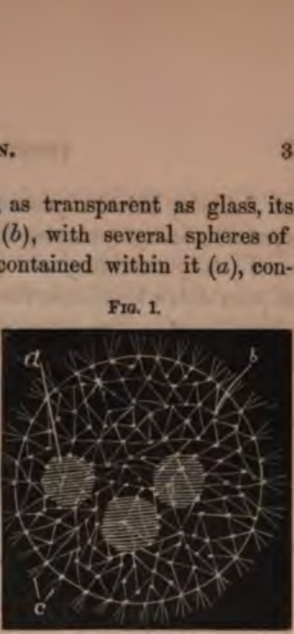
11. When its own term of life is completed, it bursts, and liberates the reproductive germs contained in its interior, and sets them free, each being capable of going through the like series of operations; or the cell wall is absorbed, thus freeing the germ.

12. These facts are illustrated by the accompanying figures of *Volvox globator*, described by Professor Ehrenberg, as an *animal*, but which has long been known as a simple fresh water alga. A perfect figure of this beautiful organism is shown at Fig. 1.

13. The Volvoces are only to be found in stagnant pools of clear, pellucid water; placed under the field of a Microscope, they present a very charming sight. In form a perfect sphere, the membrane con-

stituting the outer wall, or integument, as transparent as glass, its surface covered with minute green dots (*b*), with several spheres of variable size, and much darker green contained within it (*a*), contribute to form an object of unequalled beauty!

FIG. 1.



Volvox globator.

14. Neither is this all; those persons who see it for the first time, will be surprised to find that it (a plant) is *locomotive.*

15. It will constantly be seen rolling to and fro, with a remarkably steady, equable motion; no obstacle retards it—nothing accelerates its speed: frequently it occurs that two of them are seen approaching each other in opposite directions; collision appears to be imminent, but just at the instant of anticipated conflict, one turns off to the right, and the other to the left, and each pursues its way.

16. The locomotive organs are not easily seen, even by the Microscope—two essentials are necessary; firstly, an excellent *fourth* achromatic object glass,* and, secondly, careful and judicious management of the light. These conditions being established, a number

* Certain expressions have been used in this work which require explanation; thus, in speaking of the magnifying power employed, "a fourth," or "an eighth" object glass is mentioned.

An *Achromatic* object glass, if of French construction, consists of *three plano-convex lenses;* if English, of *three pairs* (six) of lenses. The focal length of such combinations, always short, may yet be of variable length, while the magnifying power may be the same, therefore *focal length* forms no indication of magnifying power.

For the perfect demonstration of the latter, it is usual to use the achromatic combination *as a single lens*, and test its exact capabilities by comparison with *a single plano-convex lens*, and then to name the former by the focal length of the single lens, with which it agrees.

An "inch" achromatic means that the glass is equivalent to a plano-convex lens *with an inch focus*—in other words, that it magnifies exactly *ten diameters:* a "fourth," or an "eighth," mean that they are equal to plano-convex lenses, of one-fourth or one-eighth of an inch focus, or 40 or 80 diameters.

In the Compound Microscope, there are two additional modes of obtaining an enlarged image, beyond the use of the object glass; these are, the length of the tube of the compound body, and the eye-piece. The legitimate way to obtain power is by the object glass, as, although the other two plans may greatly enlarge the image, they are powerless to show structures that the object glass fails to develop.

The great number of diameters pompously claime. by some authors, depends entirely upon *the length of tube and depth of eye-piece*—both of them objectionable (frequently fallacious) modes of obtaining magnifying power. The best and fairest way is to state the value of the object glass employed.

of delicate, hairlike processes, in constant vibration, will be seen *against the light*, surrounding the outer margin of the globe (*c*); once clearly seen, they will readily be discovered, *arising from the minute dots* which cover the external surface (*b*). By their incessant vibratile action, the rolling motion results, for which these plants are remarkable.

17. These organs are called *cilia*, from the Latin word *cilium*, an eye-lash, which they are supposed most nearly to resemble; and, from their action, *vibratile cilia*. These plants are large enough to be seen, when held against the light, by good, unassisted vision.

LESSON II.

INTRODUCTION, CONTINUED.

18. Not only are the perfect forms, or parent plants, seen in incessant motion, but the large green masses (*a*), so conspicuous in the interior, are also in constant rotation, until, when they have become mature, they desire to effect their liberation and commence an independent existence; at this period they will be seen to have numerous small, immature germs in their interior, also in motion.

FIG. 2.

Volvox globator, burst.

19. The mode by which they escape is by the rupture of the parent cell (Fig. 2); here a decided break in the cell-wall is seen, and one of the germs, covered with vibratile cilia, has just effected its liberation, to be speedily followed by the remainder.

20. The higher forms of vegetable life are only distinguishable from the lower forms by the *multiplication of similar* cells, so that by the concurrent labors of all, a more complete and lasting effect may be produced.

21. The analysis of even the mighty monarch of the forest, shows that all the soft and growing parts are composed of similar cells; their function is to absorb and prepare the nutriment, which is afterwards

to be applied to the extension of the solid internal skeleton of the trunk and branches.

22. At the extremities of the roots of all the more perfect plants, we find a set of soft cells, making up those succulent bodies which are known as the *spongioles;* these are specially destined to perform the *absorption* of nutritious fluid.

23. This fluid, being conveyed by the vessels of the stem and branches to the leaves, is here subjected to the action of the cells which make up the parenchyma (pulp) of these organs.

24. The crude, watery, ascending sap, is thus converted, by a variety of chemical and vital operations, into the thick, glutinous *latex;* which, like the blood of animals, contains the materials for the production of new tissue, and also the elements of the various secretions.

25. This process of conversion includes the *exhalation* of superfluous liquid, and also that interchange of gaseous ingredients between the sap and the air, which may be termed *aeration;* but it involves, besides these obvious chemical alterations, a new arrangement of the particles of the sap, by which a variety of new products are generated, some of them possessing a tendency to pass into the form of solid organized tissue, by a process of coagulation, when withdrawn from the living vessels. To this peculiar converting process, which is such an important step towards the production of perfect living tissue from the crude aliments, the term *Assimilation* is applied.

26. ASSIMILATION, therefore, is the peculiar process by which foreign substance is converted into the likeness of the individual. Thus the food *assimilated* by a plant, becomes *identical with itself;* and on the same principle, Man, in common with other animals, *assimilates* or *converts* his and their food. As the elaborated sap descends in its proper vessels through the stem, it yields up to the growing parts the nutrient materials they respectively require. These growing parts may be the ordinary tissues, of which the chief part of the fabric is composed, and which are destined to a comparative permanency of duration; and in the growth and extension of these, the process of *Nutrition* is commonly regarded as consisting.

27. By NUTRITION is meant the food which promotes the growth of plants, and promotes the growth and repairs the waste in animals. On the other hand, certain groups of cells have for their office the separation of peculiar products from the sap, such as *oil* (fixed or essential), starch, resin, &c., which they store up against the time when they may be demanded: these cells are said to perform the act of *Secretion.*

28. SECRETION, in plants, consists in the process of separating from the sap *materials differing from itself.* This function is delegated to *cells*, in the Vegetable Kingdom, but the allied function in the Animal Kingdom is performed by *glands*. In them resides the power of *secerning* or *secreting* from the blood, substances entirely different from it, or any of its constituents, as *bile, saliva, mucus*, &c.

29. It is very important to remark in regard to all the cells thus actively concerned in the Vegetative functions in plants, by which the development and extension of the permanent fabric is provided for, that they have but a very transitory life as individuals.

30. The *Absorbent* cells at the extremities of the rootlets are continually being renewed; some of the old ones dying and decaying away, whilst others are converted into the solid texture of the root, and thus contribute to its progressive elongation.

31. In the process of ABSORPTION, another broad distinction occurs between Plants and Animals. In the former kingdom, this, like all other vegetative functions, is performed by *cells;* but in the Animal Kingdom the *imbibition*, or *absorption*, is performed by special vessels, as the *lacteals* (*lacta*, milk,) and *lymphatics*.

32. Of the transitory duration of the Assimilating cells, we have an obvious proof in the fall of the leaf; which takes place at intervals, to be followed by the production of a new set of cells, having similar functions.

33. The fall of the leaf results merely from the death and decay of its tissue; as is evident from the fact, that, for some time previously, its regular functions cease, and that, instead of appropriating carbon from the atmosphere, there is a liberation of carbonic acid (a result of their decomposition) in large amount. Thus, the process takes place in evergreens equally with deciduous (falling off) plants; the only difference being, that the leaves in the latter are all cast off and renewed together, whilst in the former they are continually being shed and replaced, a few at a time.

34. The *Secreting* cells have usually a like transitory duration; being destined to give up their contents by the rupture or liquefaction of their walls, whenever called upon to do so, by the demand set up in the growing parts of their neighborhood, for the peculiar products they have set apart.

35. Not only are the proper organic functions of all Plants thus dependent upon the agency of cells, but their *Reproduction* is so likewise.

LESSON III.

INTRODUCTION CONCLUDED.

36. REPRODUCTION, to renew that which has been destroyed. Trees are *reproduced* by new shoots from the roots, or from cuttings or slips. Some animals, as the Lobster, Crab, &c., possess the power of *reproducing*, or generating lost parts. In the lowest tribes of the Cryptogamia, where each cell is an independent individual, every one has the power of preparing within itself the reproductive germs, from which new generations may arise.

37. The GERM is the origin, or first principle; that from which any thing springs. In botany it is the ovary or seed-bud of a plant, the rudiment of fruit yet in embryo. In the higher plants we find a complex apparatus superadded for the purpose of aiding the early development of these germs, by supplying them with nutriment previously elaborated by the parent; yet still this operation is of a purely *accessory* kind, and the *essential* part of the process remains the same.

38. Now we shall find that although the fabric of Animals appears to be formed on a plan entirely different from that of Plants, and although the objects to be attained are so dissimilar, there is much greater accordance amongst their elementary parts, than might have been anticipated.

39. The starting point of both is the same; for the embryo of the Animal, up to a certain grade of its development, consists, like that of a Plant, of nothing else than an aggregation of cells.

40. The lowest class of animals, the Microscopical Animalcula, or the invisible inhabitants of stagnant water, appear to be identical with the simple cellular plants, already referred to (*Volvox globator*). The bodies of these creatures are singularly elastic, and remarkable for their transparency. The whole of this class (animalcules) are locomotive in a high degree, and by the means of similar organs—vibratile cilia. Unlike the uniform progression of the plant, these creatures exhibit the most astonishing irritability.

41. Whilst swimming along at a rapid rate of speed, pursuing their prey, a portion of vegetable matter or some extraneous substance will arrest their career; suddenly, they throw out the water with which their interior was distended, and instantly contract to such a speck as to become perfectly invisible.

42. Every thing remaining still and quiet, they re-fill their bodies with water, the vibratile organs again appear, motion is resumed, and off they go.

43. During the time they remain passive, which often occurs, they can be examined with great ease; it will then appear that their body contains a variable number of distinct globular particles, to which Ehrenberg ascribes the function of gastric cavities or stomachs.

44. According to the same authority, many of these creatures possess not less than three hundred of these cells, or stomachs.

45. Now, the probability is, judging especially from the analogy furnished by the vegetable kingdom, that these spots are only *nuclei*, or immature germ spots, waiting the period for their full development, and the mode by which these creatures propagate, appears to confirm this opinion.

46. The *Enchelis pupa*, a beautiful flask-shaped animalcule, is one of those animals that should greatly assist our inquiries. When fully extended, and active, the creature presents a row of vibratile cilia (*a* Fig. 3), surrounding the oral (mouth) aperture (*b*), whilst the spots, or nutrimental sacs of Ehrenberg, are referred to at *c*.

FIG. 3.

Enchelis pupa.

FIG. 4.

Enchelis showing constriction.

FIG. 5.

The same, further advanced.

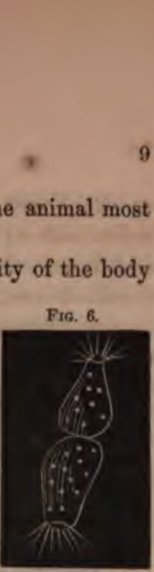
If a specimen be followed by the stage adjustments of the microscope, a slight notch or constriction will appear (Fig. 4, *a*) surrounding its body as if a fine thread were tied around it.

47. This constriction will rapidly increase (Fig. 5), and by this time a series of vibratile organs will be developed at the other extremity of the body. The incessant vibration of the cilia causes a vortex in the water, by means of which particles of matter, as well smaller animalcules, as extraneous substances, are driven to the creature's mouth: if proper food, it is immediately swallowed; but if it consist of deleterious matter, the mouth is instantly closed,

the cilia are either quiet, or entirely disappear, and the animal most frequently rushes from the spot.

48. At the time that cilia appear at each extremity of the body (Fig. 5), *two mouths are formed*, and the animal pursues its prey, and receives food at both. But still the constriction continues to advance, until the body is nearly cut in twain—the two portions being joined by the *merest pedicle* (Fig. 6); presently this becomes absorbed, and the two bodies, thus evolved by spontaneous scission, swim off in contrary directions, never again to meet in this world!

FIG. 6.



Development of the Enchelis.

49. Each half of the body, thus divided, is equally young, and rapidly attains maturity, which is no sooner accomplished, than the same process is repeated, and this continues without intermission in the Enchelis (and allied animals), throughout the summer and autumnal months, until, at the approach of winter, other modes of continuance of the species are resorted to.

50. Throughout these changes, however, it will be seen, that a fair distribution is made of the germ cells (if such they be); one half of the divided body may have a few more of them than the other, but they visibly increase in both immediately, and continue so to do till the time arrives for self-division.

51. A mode of reproduction in the lower plants, is identical, in every respect, to the spontaneous division of the body in the lower animals.

52. A species of *Conferva*, commonly called "Frog's spittle," and erroneously supposed to be the ova of that animal, has been watched, and carefully traced through corresponding developments.

53. When the plant is first collected, it may consist of a long chain of distinct cells (Fig. 7), each having a septum, or partition, at either extremity which separates it from the cell above, and below (*a*, *b*); in the centre is a mass of *endochrome* (internal green), or *chlorophylle* (green of a leaf), possessing a number of nucleated spots (*c*).

54. In a few days the cell would be seen to elongate considerably (Fig. 8), and the mass of endochrome diffuse itself confusedly, within the cell, till eventually it assumes the form of a beautiful double spiral coil (*a*), the nuclei being greatly decreased in size.

55. Presently, another phase presents itself; the *cell* becomes still more elongated, and narrower (Fig. 9), the mass of endochrome

suddenly contracts in bulk, and seeks the centre of the cell, then it *spontaneously divides* (*a*, *a*), at the same time a delicate line is run, as it were, across the cell—dividing it into two—immediately beneath the divided endochrome (*b*).

56. Subsequently, the divided endochrome seeks the centre of each cell, the spiral coil is broken up, and the entire mass assumes

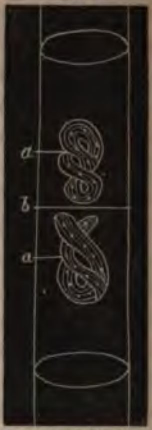
FIG. 7.

Zygnema (Frog's spittle) in the first stage.

FIG. 8.

Development of Zygnema, progressing (second stage).

FIG. 9.



Spontaneous division (third stage).

the solid cylindrical form which characterized the first figure of this series; the cells become well formed, and grow correspondingly with the increased size of the endochrome, and especially of its nuclei—the whole cell, in fact, is preparing to go through the like series of consecutive changes, in which it originated.

57. Again, as regards the vegetative type of the original constitution of animal tissues, we find among the lowest tribes of animals, as well as among certain of the highest tribes that retain many embryonic peculiarities, even in the adult condition, a great proportion of the complete fabric to be possessed of a distinct vegetative origin. In most of the higher animals, however, a large proportion of the structure consists of tissues in which no distinct trace of a cellular origin appears to be apparent; and it has been only since improved methods of observation have been brought to bear upon their analysis, and more especially since they have been examined not only in their complete state, but in the course of their development, that they have been reduced to the same category with the tissues of plants, and of the lower animals.

58. Other tissues, which are peculiar to animals, cannot be referred to the same origin; but these will be found to have a grade of organization even lower than that of simple isolated cells, and to be referrible to the solidification of the plastic or organizable fluid prepared by the assimilating cells, and set free by their rupture.

59. We shall find, however, that (as in plants) all the tissues most actively concerned in the vital operations, retain their original cellular form; and it will be easy to refer to distinct groups of cells in the bodies of animals, not merely for the performance of the functions of Absorption, Assimilation, Respiration, Secretion, and Reproduction, which are common to them with plants, but also those of Muscular contraction, and Nervous action, which they alone perform.

LESSON IV.

ON THE STRUCTURE OF VEGETABLE TISSUES.

60. All the tissues of plants are remarkable for their simplicity of structure, as compared with the tissues of animals.

61. In their earliest and simplest condition, plants are found to consist of a series of minute vesicles, composed of a membrane called *cellulose*.

62. It is also known as *simple membrane*, and possesses characteristics which distinguish it from all other tissues, that is to say: it is *elastic*, *transparent*, easily *permeable by fluids*, and *structureless*.

63. It constitutes the basis of all vegetable tissues, and it is universally present. With regard to its chemical characters it appears to be closely allied to *starch*; treated with sulphuric acid, it turns yellow; when, if subjected to the action of tincture of iodine, a beautiful purple color results, indicating the *iodide of starch*.

64. As the higher plants advance in growth, they are found to consist of *two* kinds of tissue—*cellular* and *vascular*, and these are variously modified to form the *elementary organs*.

65. By their union, the elementary tissues form the *compound* organs, by which the several functions of plants are carried on.

CELLULAR TISSUE.

66. By the conjunction of a series of minute *vesicles*, *utricles*, or *cells*, this tissue is formed. They appear to be perfectly spherical

when first developed, but the elasticity of the membrane composing their cell-wall, readily yields to the pressure of surrounding like cells, by which they assume an egg-shape or *elongated* form (Fig. 10); they are often *angular* (Fig. 11), or even polyhedral (many sides) (Fig. 12).

FIG. 10.

Single cell of Pineapple.

FIG. 11.

Cells of Cucumber.

FIG. 12.

Polyhedral cells.

67. Again, the *size* of cells is found to be as variable as their figure, in different plants, and in different parts of the same plant.

Dr. Hook counted more than a thousand in a line, an inch long, in Cork!

68. Notwithstanding each cell originally consists of a separate membrane, the walls of contiguous cells may become united in the progress of growth.

69. When cells are united at their extremities, it frequently happens that the walls, which form *the point of junction*, become absorbed, and thus a *tube* is formed.

70. The simplest kinds of plants, as Sea-weeds, are called *cellulares*, being entirely composed of cellular tissue; so too the *pulpy* parts of *fruits* and *vegetables*, and it is the great object of Horticulture to extend, as far as possible, the production of this tissue.

71. The *pith* of trees and plants is cellular; and such is the structure of cotton and rice-paper.

72. Cells generally transmit fluids through the parietes of the cell-wall, to which rule some mosses and other plants offer exception; in them, minute apertures, or holes, are found in the cells—in a single cell of a *Euphorbiaceous* plant, as many as forty-five openings have been counted.

73. Another form of cell is known as the *porous* cell, in which the membrane has been thickened at certain parts, leaving thin round spots, which, viewed by transmitted light,* appear like holes (see Fig.

* There are two modes of illuminating objects seen by the microscope; one is, to throw light *upon* the object—this is called *direct light*. The other plan consists in throwing light *through a transparent object*—this is called *transmitted light*.

Fig. 13.

Pith of Elder, porous cells.

13), of which the accompanying figure of the pith of Elder affords a good example. Authors have figured this tissue as if composed of many sides (polyhedral), but this appears to have arisen from the section being too thick; the tissue is a singularly transparent one, and if three or four layers of cells be present, the outlines of the cell walls run together in such manner as to create great confusion; this is shown in Fig. 14; but if the section do not include more than *two* layers (Fig. 13), it will be seen that one layer is simply aside of the other.

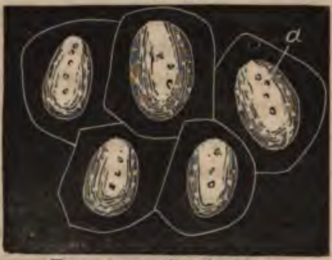
74. But to return to Cells; we have seen that the envelopes, or outer walls of these, are composed of *Cellulose*; generally, they are found to possess contents of some kind. The Cellulose itself is composed of *sugar*, *gum*, or *vegetable* jelly, which offers another form of its chemistry, and while all plants are made up of similar cells, the chief difference amongst them consists in the different *form* of the cells.

75. It frequently happens that only a *nucleus* is found; this differs materially in size and color; thus in the fruit of a ripe *Cherry* (Fig. 15), we have a series of cells widely differing in size, each con-

Fig. 14.

Pith of Elder, according to authors.

Fig. 15.



Transverse section of a Cherry.

taining a large, fleshy, brownish-colored nucleus (a), the size of which approximates to the dimensions of the cell containing it. Its surface is seen to be covered with a series of minute spots, of greater intensity of color—the nucleoli, or smaller nuclei.

76. Other cells are formed for the reception of special contents, which, as will be hereafter seen, are extremely various.

77. At the head of this list, however, *fecula*, or *starch*, in relation to human necessities, is most conspicuous; almost *two-thirds* of the human family being nourished *exclusively upon Starch.*

78. This very valuable product constitutes an important element of all the cereal (edible, as wheat, etc.) grains; it forms the nutritive principle of the leguminous plants (*Peas*, *Beans*), and is more or less actively distributed throughout the vegetable kingdom. It occurs in every plant, and it is found in every part; it will only pay the cost of separation, however, when found in the *root*, *tubers*, *seeds*, *fruits*, and (more easily, as in the Sago Palm) the *pith*.

FIG. 16.

Section of Potato, showing the starch in situ.

FIG. 17.

Corpuscle of Potato Starch, magnified.

FIG. 18.

Corpuscle of Tous les mois, magnified.

79. The Potato (Fig. 16) is found to consist of cells of variable size, formed of cellulose, and filled with corpuscles of *starch*; these, too, vary remarkably, some being very large, others minute, and the remainder of intermediate size, so that every cell may be *quite full*.

80. Examined by the Microscope, a corpuscle of starch (Fig. 17) is a very interesting and beautiful object; each corpuscle possesses somewhere, but its situation is uncertain, a circular spot called the *hilum*; this is (erroneously) supposed to be its point of attachment to the cell-wall. Around the hilum, a number of extremely delicate, transparent, concentric rings are seen.

81. The observer will, however, sometimes look for these characteristics in vain—not a single corpuscle of the veritable tissue is found to display them! The secret is that the hilum and concentric lines are placed only on *one side*, and the *other side* chances to be uppermost.

82. The largest known corpuscles of starch in the vegetable kingdom are found in *Canna coccinea*, or *Tous les mois* (Fig. 18), a plant extensively cultivated in the South of France; the peculiar French name signifies "every month," and is given to the plant from the circumstance of its flowering monthly; here the hilum and concentric lines are distinctly seen.

83. There are no two forms or species of starch *precisely alike*, and the points of difference, although frequently minute, become characteristic; thus it will be seen that the starch of Indian corn (Fig. 19) differs materially from the forms yet presented.

84. The starch of *Wheat* (Fig. 20) offers another variety; here the corpuscle is nearly round, the hilum always in the centre, and only one ring surrounding it.

85. We have examined the *largest* form of starch (Tous les mois); we will now consider the smallest, *Rice*. The starch of this plant (Fig. 21) is remarkable no less for the great irregularity of its form than for its minuteness. The question has yet to be determined whether or not starch be more or less nutritive in proportion to its

FIG 19.

Corpuscles of Indian Corn, magnified.

FIG. 20.

Corpuscles of Wheat Starch.

FIG. 21.

Corpuscles of Rice Starch.

size; should it eventually be settled in the affirmative, *Tous les mois* will undoubtedly take the first rank in the category, and *Rice* the last; the Potato, and the contents of the leguminosæ (peas, beans), together with the Cereal grains, will then hold an intermediate place. The Tous les mois is such a valuable form of starch, that it is much to be regretted its cultivation has not been attempted in this country.

Now that we have a "Model Farm" in our midst, it is to be hoped the attempt to raise it will be speedily made, and the results made known, for the good of the community. There appears to be no sufficient reason why the experiment should not be eminently successful.

86. Starch is laid up by the plants forming it, as a store of nourishment upon which they can draw for their subsistence in a season of need; hence, the quantity yielded differs in the same plant at different periods of its growth. Thus, starch abounds in the potato towards the latter part of the season, but it decreases in Spring, because of the germination of the tubers, which at such a time require to appropriate it.

LESSON V.

THE SUBJECT OF STARCH CONCLUDED.—GUMS AND SUGARS.

87. It was found by experiment that 240 lbs. of potatoes left in the ground, contained of starch:

In August	23 to 25 lbs.
" September	32 " 36 "
" October	32 " 40 "
" November	38 " 45 "
" April	38 " 28 "
" May	28 " 20 "

88. The quantity of starch remained the same during the dormant state in Winter, but decreased as soon as the plant began to grow, and to require a supply of nutriment.

89. Starch exists in roots, stems, the receptacles of flowers, and in pulpy fruits. The stem of the *sago palm*, the receptacle of the artichoke, and the pulp of the apple, are situations in which starch is found.

90. Instances are not wanting in which starch, used for human food, is found associated with the *deadliest poison*; thus in *Jatropha manihot*, a euphorbiaceous plant, the Indians, while engaged in obtaining the *tapioca* of commerce, or cassava-meal, dip their arrow-heads in the fluid that exudes, to the intent that they may be thereby *poisoned*. A more fatal poison is not known than the deadly milk of this euphorbiacean!

91. Amongst the Cereals none are more valued for nutrient qual-

FIG. 22.

Section of a grain of wheat.

FIG. 23.

Oryzopsis asperifolia, or Mountain Rice.

ity than *wheat*; this appears to arise from another element abundantly found associated with starch in this grain, viz., *gluten*. A portion of a grain of wheat, highly magnified (Fig. 22), displays the *pericarp* (*a*), showing a number of vessels cut through; the epis-

perm (*b*), an intermediate layer (*c*), the gluten cells (*d*), and the starch cells (*e*).

92. It is well known that *rice* contains very little nutriment, yet a wild species, found abundantly in Wisconsin, and known as *mountain rice*, appears to offer an exception to this rule. In a highly magnified view of a section of *Oryzopsis asperifolia*, or mountain rice (Fig. 23), we see the *pericarp* (*a*), of great substance, and filled (apparently) with bordered pores. To this succeeds (*b*) the episperm, followed by an intermediate layer (*c*), and beneath this layer the gluten cells (*d*), as in the Triticum (wheat). Lastly, we find the cells (*e*) containing the minute corpuscles of starch.

93. In addition to the microscopical test for starch (hilum and concentric rings), there is a simple *chemical* test of much importance, i. e., the Tincture of Iodine; this re-agent has been briefly alluded to above

94. If a tissue suspected to contain starch be treated with a minute quantity (the less the better) of this fluid, and *starch be present*, a beautiful purple color is the immediate result; by this simple process a new combination is formed—the *iodide of starch.* Tincture of iodine fails to produce a similar effect upon any other known vegetable tissue, and hence it may be regarded as an unfailing test of the presence of Fecula.

95. By the action of malt, or of sulphuric acid, or by long boiling in water, a gummy matter is produced from starch called *dextrin*, or soluble starch. This material is now abundantly used as a cheap and efficacious form of gum for envelopes, postage stamps, &c. By many authors it is supposed that *dextrin* is formed of the substance contained in the interior of the corpuscles; at all events, the formation of dextrin is one of the first steps in the conversion of starch into sugar.

96. GUM is a substance abundantly produced in the vegetable kingdom. It is found in many seeds, exudes from the stems and twigs of numerous trees, and is contained in the juices of others from which it does not exude.

97. The different kinds of gum have been divided into those which are soluble in cold water (gum arabic and mucilage), and those which only swell up into a gelatinous matter (tragacanth, cerasine, and pectine.)

98. Gum arabic, or gum senegal, is produced by various species of acacia, chiefly natives of Arabia; hence its scientific name, gum acacia, or, on the other hand, its common name of gum arabic.

From the bark of these trees it exudes as a thick juice, which subsequently concretes into *tears*.

99. Gum arabic is combined with *cerasine*, in the gum of the cherry and plum.

100. Mucilage is found in many of the mallow tribe, as *marsh mallow*, and in *linseed*.

101. CERASINE is that part of the gum of the cherry (*cerasus*), plum, and almond trees which is insoluble in cold water.

102. PECTINE is a substance procured from *pulpy* fruits, as the pear and apple; it forms a jelly with water, and when dried resembles gum, or isinglass.

103. SUGAR is a substance which exists in many plants; they have been divided into those which undergo vinous fermentation, as cane, and grape sugar, and those which are not fermentesible, as mannite.

104. Cane sugar comes from the sugar-cane (*Saccharum officinarum*), beet-root (*Beta vulgaris*), sugar-maple (*Acer saccharinum*), Chinese sugar-cane (*Sorghum sativum*), and many other plants.

105. MANNITE is the chief ingredient of manna, which exudes from the *Ornus europœa* and *Ornus rotundifolia;* it is exported from Sicily and Calabria, under the name of *flake manna*. It is also found in mushrooms, celery, and many species of sea-weeds.

LESSON VI.

OILS, WAX, CHLOROPHYLLE, RESINOUS PRODUCTS, CAOUTCHOUC.

106. Oil abounds to a great extent in the vegetable kingdom, and cells appear to be formed for its special reeeption; it seems to hold the same relation to the vegetable that fat holds to the animal kingdom.

107. This substance is chiefly met with in the *seeds* of plants; it is highly nutritious (*to the plant*), and appears to nourish the embryo, until organs are developed capable of obtaining sustenance from other sources.

108. The oils found in plants are either *fixed* or *essential*. The former are found (drying oil) in *linseed; fat oils* from the olive (*Olea europœa*), and solid, as lard, in the palm.

109. The fat oils contain a large quantity of *stearine*, and are hence used as a substitute for animal fat in the composition of can-

dles, and for greasing the wheels of locomotives and cars on railroads, especially in Europe.

110. The valuable properties of castor oil, obtained from the seeds of *Ricinus communis*, as a medicine, are well known.

111. THE ESSENTIAL OILS occur in the stem, leaves, flowers and fruit of many odoriferous plants, and are procured by distillation with water; they are called *essences*, and contain the concentrated odor of the plant. The most conspicuous of these are the oils of cinnamon, otto or attar of roses, of peppermint, caraway, cloves, &c.

112. Amongst the seeds of plants used for human food, or *nuts* as they are called, the almond claims attention. If a thin section of it be made, and submitted to the microscope, a number of cells (Fig. 24) filled with a concrete oil will be seen. The masses into which it resolves itself are of a variable size; there is some difficulty in making these preparations and preserving them, as the oil frequently quits the cells, and follows the knife; moreover, the great density of the preserving fluid, causes the oil to flow out of the cells, and fuse

FIG. 24.

Section of Almond, showing oil in situ.

FIG. 25.

Section of Cocoa-nut.

into large patches on the outside of the tissue; cells thus emptied are shown in the figure.

113. The cells of the Cocoa-nut also contain a concrete oil (Fig. 25), which, obtained by pressure, possesses much value as an oil for lamps, and a material in the composition of candles.

114. WAX is another peculiar fatty substance, sometimes found in the stem and fruit of plants. It is procured from several species of Palms, the candle-berry Myrtle (*Myrica cerifera*, and *Myrica cordifolia*); it is also found on the external surface of fruits, forming the *bloom* of grapes, plums, &c., and on the leaves of many plants.

115. It is a popular opinion that the honey-bee forms, secretes, or

deposits, the wax required to build its cells; this, however, is a mistake, wax being solely a *vegetable product*, and neither the bee, nor any other animal, is capable of secreting it.

116. During the active season of the year, when this material is most needed, the bees seek those plants which their instinct tells them supply the wax.

117. They possess the power of collecting it in a state of great purity—free from the extraneous materials with which it is more or less combined.

118. With their jaws, they fashion it into thin scales, and place them between the plates of the abdomen for safety, to be conveyed to the hive for use.

119. Well may this singularly industrious little creature be called *laden;* with its stomach filled with nectar to be converted into honey, its abdominal rings lined with cakes of wax, and the hollow spaces or baskets of its thighs, and the hairs of its body filled, or covered with grains of pollen for bee-bread.

120. The secretion of the ceruminous glands (ear-wax) of animals, differs altogether from vegetable wax.

121. CHLOROPHYLLE, or the green coloring matter of leaves, is allied to wax, being soluble in ether and alcohol, but insoluble in water.

122. RESINOUS PRODUCTS.—The milky and colored juices of plants frequently contain *resins* mixed with volatile oils, in the form of balsams.

FIG. 26.

Lactiferous vessels.

123. These are either *fluid* or *solid;* the former may be illustrated by the Balsam of Tolu, Balsam of Copaiva, Carpathian Balsam, Strasburg Turpentine, Canada Balsam, and many others. The solid forms may be illustrated by common resin. Burgundy pitch, Mastic, Sandarach, Elami, Guaiacum, Dragon's blood, and others.

124. CAOUTCHOUC (India-rubber) is analogous to essential oils; it is found associated with them and resinous matters, in the milky juice of plants. It is procured from various species of Ficus, as Ficus elastica, &c., by wounding the plants.

125. A kind of Caoutchouc, called *gutta percha*, imported from Singapore, and Borneo, is procured from Iso-

nandra Gutta; the chief difference between this gum and India-rubber appears to be, that the milky juice that yields it (the latter) contains a greater amount of starch.

126. The milky juice, above referred to, is contained in a system of distinct vessels (Fig. 26), called *lactiferous* (*lacta*, milk) ducts; this structure may be easily seen in the India-rubber tree (*Ficus elastica*), Dandelion, Lettuce, Celandine, and the various species of Ficus and Euphorbia.

127. Some of these milky juices are bland, as in the Cow-tree (*Galactodendron utile*); others are narcotic, as in the Poppy and Lettuce; others purgative, as Gamboge; others diuretic, as Dandelion (*Taraxacum*).

LESSON VII.

RAPHIDES.

128. In addition to the various forms of cell—contents already enumerated—mineral matter, having either lime as its basis, or silica (flint), is abundantly found. Where flinty matter obtains, it frequently assumes an *acicular* or needle-like shape—hence called *Raphides*, from the Greek *raphis*, a needle.

129. The *needle* shape is not, by any means, universal; they are as frequently found of a *Stellate* (star) form, and not unfrequently as single crystals, having an octohedral (eight sides), rectangular (right angled), or prismatic (in form of a prism) form.

130. No part of the plant appears to be free from them; they are found in the stem, bark, leaves, stipules, sepals, fruit, root, spiral-vessels, and even in the pollen.

131. Some plants are known to secrete *Oxalic acid*, which is a fatal poison to man, and many other animals.

132. To counteract the effect of this vicious material, and neutralize it, such plants (*Onion*, *Pie-plant* or *Rhubarb*), feed greedily upon *Carbonate of lime*. This earth has great affinity for the oxygen of Oxalic acid; they seek each other, combine, and in the form of crystals of varying figure, the new compound is deposited in cells as the *Oxalate of lime*—a perfectly innocuous combination.

133. By this simple and beautiful arrangement, delicious and nutritious vegetables are redeemed to the use of man, which, otherwise, would prove speedily fatal to him.

134. If the thin, transparent, and dried outer layer of a ripe onion be submitted to the microscope, a beautiful assemblage of crystals of this newly formed mineral will be seen in the cells respectively (Fig. 27).

FIG. 27.

Raphides; Onion containing prismatic crystals of Oxalate fluid.

135. These are sometimes octagonal; frequently prismatic.

136. When the lime has been sufficiently abundant, and the fruit is well developed, and of large size, it is usual to find more than one crystal in a cell; whenever this occurs, they *always form crosses*, sometimes composed of two, frequently of a plurality of crystals.

FIG. 28.

Raphides, Rhubarb.

137. The root of the Pie-plant (*Rhubarb*) contains a vast number of *stellate* crystals of oxalate of lime. (Fig. 28.)

138. The common English rhubarb, so abundantly cultivated in our Gardens, and offering such a delicious, and highly nutritive material for pies and tarts, in advance of all other fruits, contains a far less amount of this mineral than the Turkey Rhubarb, so valuable as a medicine. In the latter, it exists to so

FIG. 29.

Raphides, Beet-root.

FIG. 30.

Melon Cactus, the cells of which contain raphides.

FIG. 31.

Encephalatus pungens, containing starch and raphidian cells.

great extent, that the only test for this root, as compared with the English, which is frequently substituted for it, is to *chew* a small piece of it, when if it be found particularly *gritty* (occasioned by the crystals of oxalate of lime), its identity is assured.

139. Crystals of oxalate of lime, of the stellate form, are also found in the Beet-root (Fig. 29), the *melon cactus* (Fig. 30), and (together with starch) in a Cycadaceous plant (*Encephalartus pungens*) (Fig. 31). The bulb of the Squill plant (*Squilla maritima*) (Fig. 32) contains raphides.

140. Oxalic is not the only acid found combined with lime to

FIG. 32.

Squilla maritima.

FIG. 33.

Cells of Rumex, containing raphides.

form raphides in the plant; on the contrary, phosphoric, malic, sulphuric, and carbonic acids, all contribute to the varied forms of these crystals.

141. Phosphate of lime generally produces acicular crystals (*a*), as seen in the cells of Rumex (*Rhubarb*) (Fig. 33); the leaf of the maple also affords similar crystals (Fig. 34).

FIG. 34.

Cells of Maple leaf, containing raphides.

142. So wonderfully abundant are raphides in certain plants, that the late Prof. Bailey (of West Point) computed in a square inch of Locust-bark, the thickness of writing paper, more than a *million and a half* of these crystals!

143. Certain species of the *Cactus* tribe of plants contain such an inordinate quantity of raphides that they appear to be almost entirely made up of them; sometimes every cell of the cuticle contains stellate crystals, whereby these plants are rendered exceedingly brit-

FIG. 35.

Testa of the Elm, showing raphides.

tle, so much so, that the least touch will produce a fracture.

144. The bark of trees is a source fruitful in raphides; they are abundantly found not only in the *Locust* (as we have seen), but in the *Hickory*, *Apple*, *Pear*, &c.

145. It has been remarked that the testa (shell) of many seeds contain them, and a figure is given (Fig. 35) of the testa of the seed of the *Elm*.

LESSON VIII.

SCLEROGEN, OR LIGNINE.

146. This word comes from the Greek *skleros*, hard, and is applied to certain depositions found in the interior of cells. It is also called *Lignine*, or woody fibre; it is supposed to be a modified form of cellulose.

147. The albumen of the fruit of a Palm (*Phytelephas macro carpa*), hardened by this peculiar deposition, forms not only a most beautiful object for the microscope, but it has become an important article of commerce; handles for canes and umbrellas are turned out of this valuable substance, known as the nut, or vegetable Ivory; pipe bowls, and a variety of articles are fashioned out of it.

148. For a few months after it is gathered, it remains so soft that it may be easily cut in thin sections with a penknife, but exposure to the atmosphere inspissates it, and it becomes so remarkably hard that it can be *turned*, and highly polished in a lathe, with great ease.

149. A thin section, examined by the microscope, presents a charming appearance (Fig. 36). The cells are all distinctly visible, each one containing in its centre a vesicle composed of sclerogen, or lignine; from this vesicle a series of tubes radiate to the inner margin of the cell-wall—but they never pass through it—to an adjoining cell. In the nut ivory, the tubes are of unusual size, and have a knobbed termination.

150. Those persons who eat *pears* and *quinces*, will have observed that as they approach the seeds, in the centre of these fruits, their

teeth come in contact with a number of minute, hard particles in the pulp cells; they try to crush them with their teeth, but find them much too dense. These constitute what is called the *gritty* tissue.

151. A thin slice of a pear examined by the microscope (Fig. 37), shows that this tissue is made up of a variable number of distinct particles (*a*), which form a mass, of uncertain size, amidst the pulp cells (*b*).

FIG. 36.

Nut Ivory.

FIG. 37.

Gritty tissue of the Pear.

152. There can be no doubt that the intention of surrounding the seeds with this peculiar tissue is, to afford them a certain degree of protection; and it appears to foreshadow the more perfect development of a superior tissue designed for the same purpose (protection), met with in the cherry, plum, peach, and other fruit stones.

153. Some of the elements of the gritty tissue, of increased size, are shown in the accompanying figure (Fig. 38); in common with

FIG. 38.

Sclerogenous elements of gritty tissue, magnified 300 diameters.

FIG 39.

Testa of Nut Ivory.

other like tissues, there is a central vesicle, associated with radiating tubes.

154. The testa, or husk, of the Nut Ivory (Fig. 39), presents a very fine view of the arrangement of the sclerogen; it is only neces-

sary to grind it down thin enough to transmit light easily, and mount it in fluid as a preparation.

155. Thin sections of the *Peach*, *Cherry*, and *Plum* stones, show structures not very dissimilar; these, together with the *Hazel-nut*, *Walnut* (English), and *Cocoa-nut*, so much resemble the ultimate structure of bone, as frequently to be mistaken for it; there is only one broad character that separates them—in bone, the tubes connected with the central vesicles (here called *canaliculi*, or little tubes) freely *anastomose* (or join) throughout the tissue, whereas in vegetable similar structures, the tubes are confined within the limits of the cell-wall.

156. The Cherry-stone (Fig. 40) and the *Peach*-stone, very much resemble each other; in both the like general arrangement occurs.

157. But the culminating point of beauty of these tissues, appears to be the *Cocoa-nut*, seen in transverse section (Fig. 41). The cells and their internal vesicles are of greatly increased size, as compared with similar structures, and the connecting tubes correspondingly numerous and delicate.

FIG. 40.

Section of Cherry-stone.

FIG. 41.

Transverse section of shell of Cocoa-nut.

WOODY FIBRE.

158. Of all the forms of cells, the wood and bass-cells are most important in the domestic economy of mankind.

159. The "bass-cells" are the longest of all; their walls are generally very thick, and mostly much bent, but rarely marked with pores or spiral fibres; only in the silk plant (*Asclepias Syriaca*), the *Oleander*, and allied plants, is a spiral striation of the walls observed.

160. The materials used for ropes, cordage, linen, certain Indian muslins, mummy cloth, and mats, consist of the woody fibre of plants, from which the more delicate tissues have been removed by long-continued maceration in water.

FIG. 42.

Linum usitatissimum, or Flax plant.

FIG. 43.

Cannabis sativa, or Hemp plant.

161. Flax (or lint) is thus procured from the bark of *Linum usitatissimum* (Fig. 42), hemp, from *Cannabis sativa* (Fig. 43), New

FIG. 44.

Phormium tenax. New Zealand flax.

FIG. 45.

Yucca gloriosa.

Zealand flax from *Phormium tenax* (Fig. 44), and bass (or *bast*) from the common Lime, or *Linden tree.*

162. Fibres are also procured for manufacturing purposes from the *Pine-apple plant* (*Ananassa sativa*), from *Yucca gloriosa* (Fig. 45), from *Boehmeria nivea*, which yields the Chinese grass-fibre, from most of the plants belonging to the mallow and nettle tribes, and from some of the leguminous plants.

163. The tenacity of different kinds of woody fibre, as contrasted with silk, is given by De Candolle, thus:

Silk supported a weight of	34 lbs.
New Zealand Flax	23 4-5
Common Hemp	16 1-3
Common Flax	11 3-4

If the maceration of the fibre be carried on to much extent, a pulp is formed from which paper is manufactured.

164. In ordinary paper the vegetable structure is entirely destroyed, but in the Chinese *rice-paper*, which is not prepared by maceration, and in the paper of Japan, made from the mulberry, it is preserved.

165. The structure of flax, so largely employed in the manufacture of linen, is peculiar; and to guard ourselves against those manufacturers who employ (frequently) a large percentage of cotton, to be used in manufactures hereafter to be warranted "all linen," it is worth the while to examine it.

166. If a linen thread be scraped with the thumb-nail to separate it into its primitive elements, or ultimate fibres, and placed under the microscope, an appearance will be presented like Fig. 46.

FIG. 46.

Fibres of Flax.

167. It will now be seen that we have a series of (apparently) solid, cylindrical, many-jointed fibres—the joints not very dissimilar to those of a bamboo cane; really, however, they are *tubes*, so nearly filled with solid contents that it is by no means easy to satisfy oneself of the fact.

168. The outer membrane of the tube is structureless, although, occasionally, delicate transverse markings may be seen.

169. These tubes are of great length, and usually pointed at both ends; they are also remarkable for their toughness.

170. *Cotton* is not woody fibre, but simply the hair of the plant producing it, and will be described under the proper head.

LESSON IX.

VASCULAR TISSUE.

171. The roots of a plant absorb a continued influx of nutrient matter, which circulates through it, while the superfluous water is evaporated by the stomata (breathing mouths).

172. This movement of the sap alters the form of the cells through which it passes, and *elongates* them.

173. The walls of most of these elongated cells become thickened, they have a tendency to *aggregate*, and thus is formed, in the midst of the cellular tissue, bundles of elongated cells, or vessels, called *vascular bundles*, which to the naked eye look like dense fibres running through the tissue of the plant.

174. In one great division of plants (*Monocotyledons*), to which the *Grasses*, *Lilies*, *Palms*, &c., belong, the development of these vascular bundles stops short at a certain stage, and they undergo no further alteration.

175. In another class, on the contrary (*Dicotyledons*), to which belong our forest trees, kitchen vegetables, and many others, there is a continuous development of cells on the outer side of each vascular bundle, which become in turn *vascular bundle cells*, and so unceasingly increase the thickness of the bundles.

176. As a consequence, they gradually close up together into a firm tissue, or into that form we call wood.

177. In relation to human wants, these vascular bundles become important on account of the chief portion of their contents (the spiral fibre) constituting wood, and woody fibre, or bass.

178. Examined by the microscope, vascular tissue, in its original development, presents itself as a spirally wound coil of woody fibre, within a cell, of cellulose (Fig. 47).

Fig. 47.

Spiral vessels.

179. A *vascular bundle*, microscopically examined, displays vessels in several distinct forms; some like Fig. 47, others *becoming annular;* annular vessels perfectly formed; scalariform (*scala*, a ladder) vessels; and *old* vessels—either emptied of their contents, or filled with woody fibre.

180. There appears to be great probability for believing that spiral vessels are *always formed originally* like Fig. 47; having subserved the purpose for which they were developed, they *begin to degenerate;* this process is, however, a slow one, and no great impediment appears to accrue for some time to the transmission of the sap—not until the ligneous elements are entirely removed, or the old vessels be filled with them.

To substantiate these opinions, the following series of illustrations, drawn from existing preparations, are offered.

181. The first stage of the process of disintegration appears to be a concentration of the spiral element into a filament of greatly increased robustness (Fig. 48); the newly formed spiral then throws itself into a loose and irregular coil within the cell, the parietes (sides) of the latter becoming at this period particularly distinct; the terminations of the filament exhibit a tendency to form *rings*, which having done, by a process of absorption, they are cut off, and separated by an interval of space. This process continues till the entire tube contains only a series of rings, more or less widely separated (Fig. 49), now called *annula*, from *anellus*, a little ring.

FIG. 48.

Vessel becoming annular.

FIG. 49.

Annular vessel.

182. The process of gradual decadence (decay) does not stop here. It is very easy, by long continued maceration in water, to separate these rings from the tubular envelope, for they, being composed of woody fibre, can resist the action of water, to which the tubes of cellulose must speedily succumb. These rings, thus obtained, are shown at Fig. 50. In this view of them it will be seen that they are not *round*, but *compressed* rings, with a variable number of angles.

183. It is easy to understand that the process of absorption, already in operation to produce a series of rings out of a continuous spiral thread, does not necessarily cease, and such appears to be the fact.

184. One of the rings (A), has been divided into *eight* portions, to show the like separation which occurs in nature; absorption and concentration having firstly formed the irregular filament, and secondly divided it into a series of distinct rings, still continues, by dividing the rings respectively, all of them remaining in situ (*situation, place*), and removing a portion of each divided fragment—rounding its extremities—till a scalariform vessel (Fig. 51) results.

185. From this point the absorptive process continues, until every particle of ligneous matter is removed from the tube, which is now

Fig. 50.

Annular rings.

Fig. 51.

Scalariform vessels.

Fig. 52.

Old vessel.

called an *old vessel* (Fig. 52); this either continues permanently empty, or becomes filled with a bundle of woody fibre.

186. Spiral vessels are nearly round, annular vessels are more or less compressed tubes, but scalariform vessels preserve a beautifully symmetrical figure, while an old vessel returns to the original rounded form.

Fig. 53.

Scalariform vessels, from stem of fern.

187. The figure of the *scalariform*, as compared with the *annular* vessel, seems to arise from the fact of the annular rings being broken up, and the tube of cellulose readily yielding, between the ligneous particles, to the pressure which uniformly surrounds it. A beautiful view of Scalariform vessels, from the stem of a Fern, is given in Fig. 53, in which it will be seen that they form groups, of variable size, in the midst of the cellular tissue. There cannot be a finer exhibition of these vessels, than a transverse section of the stem of a fern discloses.

LESSON X.

POROUS AND DOTTED DUCTS.

188. In addition to the spiral, and other vessels already described, tubes or canals are also found in plants; these are called *ducts*, and give to woods their various degrees of porosity.

189. Spiral vessels can be easily unrolled—ducts possess no such capability, and hence the word *duct* is limited to such vessels as cannot be unwound.

FIG. 54.

Dotted duct of the Fir.

190. Dotted ducts are peculiar to firs, pines, and cone-bearing trees; they consist of spindle-shaped, or fusiform cells (Fig. 54), bearing a variable number, according to species, of saucer-shaped discs, each having a small circle in the centre.

191. These peculiar markings are formed by concave depressions on the outside of the walls of contiguous tubes, which are closely applied to each other, forming lenticular (shaped like a lens) cavities between the vessels, like two watch-glasses in close apposition; when seen by transmitted light they appear like discs.

192. This structure is common to, and characteristic of the cone-bearing trees; the number of discs, or ducts, in a given cell is found to differ in the several species, thus the pine (Fig. 55) has only a single row in each cell; the *pinus strobus* (Weymouth pine, Fig. 56) has two rows of discs, arranged on the same plane; whilst *Araucaria* has two and three rows (Fig. 57), arranged alternately.

FIG. 55.

Dotted ducts of the Pine.

FIG. 56.

Ducts of Pinus Strobus.

FIG. 57

Ducts, Araucaria.

193. These characters are so constant that, by the number of discs in a cell, together with the mode of their arrangement, Fossil

Coniferous woods have been easily arranged in species; a figure of fossil wood, from a cone-bearing tree, is presented (Fig. 58). In this illustration the cell is filled with four rows of alternate ducts. The small spot in the centre of each concave disc, is supposed to be all that remains of a series of vessels formerly (during the development of the plant) existing in that situation.

FIG. 58.

Single duct, from Fossil wood. (Much magnified.)

FIG. 59.

Porous tissue.

194. The vessels constituting the *porous*, *dotted*, or *pitted* vascular tissue, are continuous tubes of large size, and usually present broad or oblique extremities; but sometimes the terminations are pointed (Fig. 59). Their dotted, or pitted, appearance is supposed to depend on the mode in which the encrusting matter is formed inside. In place of being deposited equally over the whole surface of the membrane, as in ordinary woody fibre, it leaves rounded uncovered spots at various intervals, and these, when viewed by transmitted light, appear from their thinness to be perforations or holes.

195. In old dotted ducts it frequently happens, that the thin membrane of the dots, or pits, has become absorbed, and actual perforations taken place.

FIG. 60.

Dotted vessels.

196. Dotted vessels often present a jointed appearance, such as is shown in Fig. 60; in such cases, they are seen to be formed of dotted cells placed end to end, so as to form continuous cylindrical tubes.

197. Dotted ducts are abundantly found in the wood of trees, and they constitute the large rounded openings seen in transverse sections of the stems of *oak*, *poplar*, *willow*, &c. They also abound in the Bamboo, and in other plants of rapid growth.

198. Porous ducts are very numerous in the *Locust* tree, and are of great beauty (Fig. 61); it will be seen that the lower

part of one duct, and the upper portion of another is shown together with two perfect cells: the pores are bordered pores.

199. In the apple tree another form of porous vessel is found; a porous vessel with very minute pores placed in the interstices of a double spiral, suddenly bulges out into an inordinately large cell, destitute of pores, and having a number of lines, or bars, running irregularly across it (Fig. 62); it does not appear that there is any membrane between these bars, or lines, to connect them.

FIG. 61.

Porous duct, Locust.

FIG. 62.

Porous vessel, Apple.

FIG. 63.

Porous duct, Basswood.

200. But the most beautiful ducts or vessels of this kind, are found in the *Basswood;* here, they exist in great number and of considerable length, having a uniform diameter for the greater part of their course; the ends are pointed.

201. They consist of a singularly beautiful double-spiral thread (Fig. 63), in the meshes of which one, and sometimes two ducts are seen. The whole of this structure is confined in a tube of cellulose, which, under the microscope, presents a very glistening appearance.

LESSON XI.

SILICA.

202. This mineral, so abundantly found in all kinds of soils, universally throughout the surface of the Globe, is of the greatest consequence to the vegetable kingdom.

203. We have already seen that certain vegetables have a paramount necessity for the *Carbonate of lime;* with its assistance, as an article of food, they flourish, and luxuriate—without it, they perish.

204. The carbonate of lime rarely exists in its pure, original state,

but is usually associated with an acid, sometimes *oxalic*, at other times *phosphoric*, or *carbonic* acid.

205. Silica, on the contrary, is found in large quantity in vegetable tissues in all its integrity as *pure flint.*

206. There can be no doubt that the roots obtain this mineral from the earth; *elaborate*, or *digest* it, and reproduce it in a new and characteristic form.

207. Each of the grasses, for example, affords a large supply of this mineral; but the *form* and arrangement of it is *always peculiar*, and such as can only be found in that particular species, in which such form, however, is constant. It may excite our wonder and surprise to learn how it is possible for the roots of a plant to decompose, that they may feed upon such an intractable substance as flint!

208. Yet the process is a very simple and natural one: in addition to flinty materials, the earth contains large supplies of alkalies—*potash* and *soda.*

209. Silica, that resists the action of the most powerful acids, succumbs to alkalies. By union with these elements, *the flint is dissolved to a fluid state*, and forms *the silicate of potash*, or of *soda*, as the case may be.

210. The Chemist can form artificial silicates: by a process of manipulation of one kind, he forms a silicate soluble in water; by another process he makes an *insoluble* silicate.

211. By their effects it would appear that the silicates formed by nature, are (originally) *soluble;* that they are so much reduced by the addition of water as to become easy of access to the roots of the plants which absorb them; at the same time it is possible that the superabundance of the alkaline materials, may render an insoluble silicate sufficiently fluid to be appropriated by the roots.

212. Under any circumstances it is quite certain that the silica found in plants after they have elaborated it, is always perfectly insoluble. If, however, it be formed as a *soluble silicate*, then it becomes *insoluble* in the tissues of the plant—due, doubtless, to the vital energies of the organism.

213. The mode by which the tissues of plants and animals *become silicified*, or fossilized, is a very simple one: they lie beneath the surface of the earth, in and surrounded by the silicates of potash, or soda; these materials are gradually absorbed by the tissues, which, whether wood or bone, are easily accessible to the transmission of fluids.

214. By slow and insensible degrees, through a long series of years, the character of the original tissues gradually changes, the

fluid silica taking their place. None of the structures found fossilized have a tendency to decomposition, and, from the moment they begin to absorb liquid flint, this process is rendered impossible: they can afford, therefore, to wait the development of time, and whenever the circumstances are favorable, the aqueous particles are removed by evaporation, and the solid silica alone remains.

215. This process is so remarkably slow in nature, that the *soft parts* of animals are very rarely found fossil; but they, in common with bones and woods, may be easily converted into flint, artificially—and the softer the tissue (brain) the quicker and more certain the experiment.

LESSON XII.

SILICA, (CONTINUED.)

216. Silica obtains to the greatest extent in the lowest forms of vegetable life. A large class of minute (microscopical) organisms, originally classed by Ehrenberg with the animal kingdom, are now known to be vegetable, and from their possessing a double external covering, like the bivalve (*bis*, two) shells, they are called *Diatomaceæ* (*two-atoms*).

217. The loricæ (shells) of the organic structures included under this head are formed entirely of pure flint, the pattern (so to speak) being always remarkable, peculiar, and limited to species.

218. The *Arachnoidiscus* (Spider's web disc), found in Peruvian Guano (Fig. 64), is a very beautiful example; the specimen has been subject to long continued boiling in strong nitric acid—a usual method of procuring these forms for microscopical purposes—to free them from the extraneous materials with which they were surrounded; the exact, nay, *mathematical* precision with which it is divided, renders it a very remarkable illustration.

FIG. 64.

Arachnoidiscus Ehrenbergii.

219. Kindred forms are so abundant, both recent, in all the fresh-water pools, and fossil, constituting by far the greater part of the

Earth's surface, that the temptation to figure and describe them is very great; belonging to the vegetable kingdom, too, such a proceeding would be quite justifiable in this place—but it would transcend the limits of the present work.

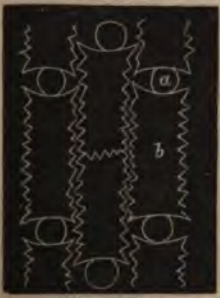
220. The grasses, which include all the Cereal grains, Canes, Horse-tails, &c., are conspicuous for the large amount of silica which enters into their composition. Who has not marvelled at the singularly erect position of a stalk of wheat, or rye, or barley, each supporting a heavy ear of grain at its summit?

221. And yet how few persons have enquired how it is, and why, that a slender stalk can grow so tall, and maintain, even against adverse elements, its perpendicular, erect form.

222. If a piece of straw of wheat, or any other cereal, be boiled in strong nitric acid, well washed in clean water, and examined by the Microscope, the secret will be developed; it will then be seen that it is defended from the root to the summit with a coat of pure, beautifully transparent silica, composed of millions of minute particles, all nicely jointed or fitted to each other.

223. Upon this principle all the grasses are defended by a *skeleton* (as it were) composed of flint. The silica of the husk (chaff) of the rye, is shown at Fig. 65; it consists of a number of long bars (*b*), connected with smaller oval bodies (*a*)—these are the casts in flint of the stomata, or breathing mouths.

FIG. 65.



Silica of Rye.

224. The husks of all the cereals, together with the hairs (paleæ), are also entirely covered with flinty matter, and those persons who indulge to much extent in the use of oat-cake, or brown bread, are liable to large concretions of flinty matter (that no stomach can possibly digest) forming in the intestinal canal, which must necessarily (sooner or later) prove fatal.

225. In the Museum of the Royal College of Surgeons, England, several such masses may be seen, all the result of post-mortem examinations.

226. The Microscope has satisfactorily determined, long ago, that some of these concreted masses are composed of silica of the oat, and others of the silica of wheat, obtained from the intestines of the inveterate eaters of brown bread, or oat-cake.

227. There is a popular prejudice in favor of this description of food, and used *occasionally*, and in *moderation*, it is well founded.

There can be no doubt that the minute particles of flint, liberated by the digestion of the food, will have a tendency to slightly irritate the mucous membrane of the ***stomach*** and ***bowels***, thereby increasing the circulation of the blood, and waking up (as it were) the dormant energies of the muscular coat of these tissues. But this increased activity is intended to ***expel*** or ***digest*** the foreign enemy, the ***flint***, and when repeated attempts of this kind end only in failure, the stomach and intestinal canal relapse into a state of increased torpor, and leave the obnoxious substance to pass, or not, as it may; these are the circumstances which originate concretions.

228. In the Kingdom of Saxony there is a mountain range of many miles extent, composed of a ***white***, ***pulverulent earth***, called by the inhabitants Berg-mehl, ***Mountain-meal.*** In seasons of scarcity, the people are wont to mix this Berg-mehl with equal parts of flour to make their bread, and assert that it is not unwholesome. During a short period in the Summer months, this practice is found in most seasons to prevail, without bad results.

229. Examined by the Microscope, the Mountain-meal is found to consist principally of a number of minute fossil diatoms, but chiefly of a form limited (almost) to this formation—*Campilodiscus clupeus* (Fig. 66). All that remains of this fossil is the flinty lorica (shell), with its minute, sharp processes, which are likely to occasion the same amount of irritation as that resulting from the flint of the wheat, or oat.

LESSON XIII.

SILICA (CONCLUDED).

230. The silicious particles of the Oat (Fig. 67) resemble those of the Rye, except that they are smaller in size; in the Wheat (Fig. 68) they are not smaller; the same ***elements*** will be found in all these illustrations, that is to say, the lengthened bar and the connecting rounded piece—a cast in flint of the breathing mouth. Moreover, the ***bars*** have all serrated (toothed, like a saw) edges, by means of which they lock into each other to form a continuous tissue, just as the bones of the human skull interlock at the sutures.

231. The flint obtained from the husk of the Rice, differs somewhat from the preceding illustrations (Fig. 69). Here we find that the bars are shorter and broader, the serratures finer and more uni-

form in size; the stomata are apparent as nucleated spots in a tortuous line, which occupies the central portion of each bar.

232. The various species of Horse-tails (*Equisetum*) are remarkable for the large amount of flint found in their cuticular covering.

Fig. 66.

Campilodiscus clupeus, from the Berg-mehl.

Fig. 67.

Silica of the Oat.

Fig. 68.

Silica of the Wheat.

One species (*E. hyemale*), or Dutch rush, or scouring rush, presents a flinty layer, which forms a fine object under the Microscope (Fig. 70).

233. The flint in this plant appears to be an accurate cast of the tissue (cuticle) with which it is in contact; every cell, and the nucleus of every cell, is faithfully represented.

234. In addition to this structure of the cells, the stomata are

Fig. 69.

Silica of Rice.

Fig. 70.

Equisetum Hyemale.

well represented, and, as will be seen by reference to the Fig. (*a*, *a*), they are *double*—the one internal, the other external. The internal breathing-mouths are the large circles, with irregular openings; through these openings, and through the transparent sides of the circles, the external stomata may be seen. These consist of a pair of lips, which open in the direction of the long axis of the plant, and,

provided with coarse serratures on their internal margins, their ends are attenuated (reduced, made thin) and accuminated (pointed).

235. The Dutch rush used to be employed extensively by cabinetmakers, to smooth their work, preparatory to polishing it, but since the introduction of *glass or sand paper*, of various degrees of fineness, it has fallen into disuse with these artisans; it is still greatly employed, however, by plaster-of-paris figure makers, to file down the seams left by the junction of the several parts of their piece-moulds, and for this purpose it is invaluable.

236. The Bull-rushes, and all the plants of this order, also contain large quantities of silica.

237. Silica, however, is not by any means restricted to the Grasses; it enters into the composition of a vast number of plants, in some of them associated with the cells of the bark—in others with the cells of the cuticles of the leaves.

238. In the latter situation it is found in a very common garden shrub, which has no vulgar name, the *Deutzia scabra ;* on the upper cuticle may be seen a series of large, exquisitely beautiful stellate crystals of flint, of (comparatively) large size(Fig 71).

FIG. 71.

Upper cuticle, Deutzia scabra.

239. On the *upper* cuticle, the stars are composed of from 3 to 6 radii, four and five rays, however, being the most abundant.

240. The under cuticle has a much more dense number of smaller stars, placed nearer together, and the rays of which amount to from 10 to 13 (Fig. 72).

241. In this country, it appears that the domestics have discovered the economic value of Deutzia, as they employ the leaves with which to rub up and brighten their tin-wares—a function they must be very capable of performing.

FIG. 72.

Under cuticle, D. scabra.

242. The quantity of Silica contained in the Canes, especially the bamboo, is very great; in the latter it is frequently found in the form of a solid layer, between the joints, called "Tabasheer."

243. Reeds, from the large quantity of Silica they contain, are said, during hurricanes in warm climates, to have actually caused conflagrations, by striking against each other, and producing flame by friction.

244. Silicate of potash in a vegetable sap may be mixed with oxalic acid, by which *oxalate of potash* and *silicic acid* will be produced, and thus the silica may be deposited in cells by this process of double decomposition.

245. When these chemical compounds meet, they mutually decompose each other in this wise: *Oxygen* has more affinity for *potash* than for the acid with which it has combined to form *oxalic acid;* it therefore quits the acid, which is *set free*, and joins the potash to form a new compound—*oxalate of potash.* Then the *silica* has more affinity for the acid liberated by the oxygen than for potash; it combines with it, therefore, and forms *silicic acid*, and thus new compounds result.

246. *Chara translucens* possesses a covering of *silicic acid*, which could only have been formed in the manner indicated; *C. vulgaris* has a covering composed of silicic acid and carbonate of lime, while *Chara hispida* has a covering of carbonate of lime alone.

LESSON XIV.

HAIRS.

247. Hairs are composed of one or more transparent delicate cells, proceeding from the epidermis, and covered with the cuticle.

248. Their form is very various; some are erect, others oblique, or they may lie parallel to the surface, as in the mullein.

249. Sometimes they are composed of a single cell, which is simple and undivided, or forked, or branched; at other times they are composed of many cells, either placed end to end, or united together laterally, and gradually forming a cone, as in compound hairs.

250. Hairs occur on various parts of plants; as the stem, leaves, flowers, seed-vessels and seeds, and even in the interior of vessels.

251. Hairs are developed occasionally to a great extent on plants exposed to elevated temperatures, as well as on those growing on lofty mountains. Different parts of plants are transformed into hairs, as may be seen in the flowering stalks of *Rhus Cotinus*, and in the calyx of *Compositæ*.

FIG. 73.

Macuna pruriens, or Cowitch.

FIG. 74.

Dionæa muscipula, or Venus' Fly-trap.

252. On the pod of the Cowitch (*Macuna pruriens*), hairs are produced with projections on their surface, which cause great irritation when applied to the skin (Fig. 73).

253. In Venus' Fly-trap (*Dionæa muscipula*), stiff hairs exist on the blades of the leaf (Fig. 74), which, when touched, cause them to close (*a*), thereby impaling the fly.

254. Cotton is simply the hair surrounding the seeds of *Gossipium herbaceum;* as they dry, they collapse into a flat band with rather rounded borders, and ultimately become twisted (Fig. 75); by these characters, the fibre of cotton can be readily distinguished under the microscope from all other tissues, and when associated with flax, can be identified, and counted with great precision.

255. The hairs most frequently met with in plants are called *lymphatic*, from their not being connected with any particular secretion. Those, on the other hand, which have secreting cells at their base, or apex, are called *glandular hairs*.

256. Glands are collections of cells forming secretions; they are either *stalked* or *not stalked.* The former are glandular hairs, having the secreting cells at the apex.

FIG. 75.

Fibres of cotton (Gossipium herbaceum).

FIG. 76.

Hairs of plants.

257. These stalked hairs are either composed of a single cell, with a dilatation at the apex (Fig. 76, A), or of several cells united together, the upper one being the secreting organ (Fig. 76, B). In place of a *single* terminating secreting cell, there are occasionally *two* (Fig. 76, C), or more (D).

Fig. 77.

Hair, Urtica dioica (nettle).

258. Hairs sometimes serve as ducts through which the secretion of glands is discharged; these are glandular hairs, with the secreting cells at *the base.* Such hairs are found in the common nettle (Fig. 77), in *Loasa*, or *Chili nettle*, and in *Malpighia*, and are usually called *stings.*

259. In the Nettle (*Urtica dioica*), they consist of a single conical cell, dilated at its base (see Fig.), and closed at first at the apex by a small globular button placed obliquely (*a*). This button breaks off on the slightest touch, when the sharp extremity of the hair enters the skin, and pours into the wound the irritating fluid which has been pressed out from the elastic epidermal cells at the base.

FIG. 78.

Hair, Drosera rotundifolia.

260. When a nettle is grasped with violence, the sting is fractured, and hence no injury is done to the skin.

261. The globular apex of glandular hairs sometimes forms a *viscid secretion*, as in the *Chinese Sundew* (*Drosera rotundifolia*). The hairs of this plant, by means of its peculiar secretion, are enabled to detain insects which chance to alight on them (Fig. 78).

LESSON XV.

CUTICLE.

262. This tissue in plants corresponds remarkably with the kindred tissue in animals, especially in man. In both it is *non-vascular*, *transparent*, more or less *thick*, and abundantly supplied *with hair*, as we have just seen.

263. In plants, it is usually formed by a layer or layers of compressed cells, which assume a flattened shape, and have their walls bounded by straight or by flexuous lines. Every leaf presents a cuticle on the upper and on the under surface, each composed entirely of cells, but in many plants dissimilar in the two cuticles.

264. The cuticle is sometimes thin and soft, at other times dense and hard. In the former case it may easily be detached from the subjacent cells; in the latter, the cells become thickened by deposits, and sometimes the layers are so produced as to leave uncovered spots, which communicate with the interior of the cell by canals passing through the thickened layers.

265. In terrestrial plants the breathing mouths (*stomata*) are placed, generally, wholly on the *under* cuticle, but some plants have in addition a few scattered organs of this description on the upper cuticle. The object of placing these important organs on the under surface of the leaf, is to protect them from the rain, which would interfere with the due performance of their function if it fell upon the surface to which they were attached.

266. Stomata open or close, according to the state of moisture or dryness in the atmosphere. By examining under the microscope, thin strips of cuticle in a moist and dry state, it will be seen that in the former case the lips are distended; they assume a crescentic or arched form, and leave a marked opening between them; while in the latter, they approach each other, and close the orifice.

267. The number of stomata varies from a *few hundreds* to *many thousands* on a surface of one inch square.

268. This fact will be best illustrated by reference to the following table:

STOMATA IN ONE INCH SQUARE.

	Upper side.	Under side.
Mistletoe	200	200
Tradescantia	2,000	2,000
Rheum Palmatum	1,000	40,000
Crinum amabile	20,000	20,000
Aloe	25,000	20,000
Clove-pink	38,500	38,500
Yucca	40,000	40,000
Mezereon	None	4,000
Pœony	None	13,000
Vine	None	13,600
Holly	None	63,600
Cherry-laurel	None	90,000
Lilac	Few	160,000

269. Stomata are not usually found on leaves always submerged; but in floating leaves they are restricted to the upper surface; neither

FIG. 79.

Cuticle, Ruscus aculeatus.

FIG. 80.

Cuticle, Ivy.

are they ever found on the upper surface of leaves which have a dense shining cuticle.

270. In *Ruscus aculeatus* (Butcher's broom, Fig. 79), the cells of the cuticle are very symmetrical, and the stomata (*a*, *a*) well seen.

FIG. 81.

Cuticle, White lily.

271. The under cuticle of the *Ivy* (Fig. 80), is distinguished by the wavy lines, which constitute the outer walls of the cuticular cells; the stomata in this plant (*a*) are well marked, and of large size.

272. In the *White Lily* (Fig. 81), the cells of the cuticle, and

the stomata, are both unusually large, and present a very beautiful view of this important structure.

LESSON XVI.

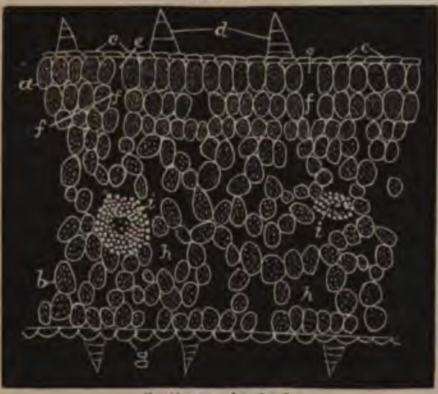
LEAVES.

273. Leaves are expansions of the bark, developed in a symmetrical manner, as lateral appendages of the stem, and having a connection with the internal part of the ascending axis. They gradually expand in various ways, acquire vascular tissue, and ultimately assume their permanent form and position on the axis. They may be divided into *aerial* and *submerged* leaves, the former being produced in the air, and the latter under water.

274. *Aerial leaves.*—These leaves consist of vascular tissue in the form of *veins*, *ribs*, or *nerves*, of cellular tissue or *parenchyma* filling up the interstices between the veins, and of a cuticular covering.

275. The *vascular system* of the leaf is continuous with the stem, those vessels which occupy the *internal* part of the stem becoming *superior*, or placed on the upper surface, in the leaf; while the more external are placed on the lower surface. The vascular system is well displayed in what are called *skeleton leaves*, in which the cellular part has been removed, and the fibro-vascular left.

Fig. 82.



Section, melon leaf.

276. The vascular system of the leaf is distributed through the cellular tissue in the form of *simple*, or *branched* veins.

277. The *parenchyma* (*para*, beside or between; *chyma*, any thing spread out, a tissue) of the leaf is the cellular tissue surrounding the vessels, and enclosed within the upper and under cuticles.

278. It is formed of two distinct series of cells, each containing chlorophylle, or green colored granules, but differing in their form and arrangement. This is best seen by making a vertical section of a leaf and examining it by the microscope. One of these layers is connected with the upper surface, and consists of compact oblong cells placed endwise (Fig. 82, *a*); the other, connected with the lower side, consists of loosely aggregated cells, having numerous cavities between them (*b*), and, when these cells have an elongated form, their long diameter is always parallel with the cuticle.

279. The cells on the upper side are usually placed close to each other, without any space between them, except in cases where stomata occur (*e*).

280. The figure (82) represents a section of a *melon* leaf, perpendicular to the surface. The upper cuticle is marked *c;* it shows hairs (*d*) on its surface, and two openings of stomata (*e*). Below the upper cuticle are layers of oblong cells (*a*), with two spaces between them (*f*), communicating with stomata. The lower cuticle (*g*), also exhibits hairs and stomata; and above it are layers of loose cells (*b*), with numerous lacunæ (openings, *h*). The vascular bundles running through the parenchyma are marked *i*.

281. In a vertical section of a leaf of the common garden Balsam (*Balsamina hortensis*, Fig. 83), we see the upper cuticle at *a;* in the section from which the drawing was made, although only one layer of cells thick, there are two, and *three layers* of the upper and under cuticle. A double series of compact, oblong cells, beneath the upper cuticle are shown at *b*, the smaller cells, belonging to the central, and under portion of the leaf, *c;* between this layer are two spiral vessels, *d;* the under cuticle, containing numerous stomata, *e*.

Fig. 83.

Transverse section, leaf of Balsam.

282. The green color of leaves is wholly due to the *chlorophylle* (*chloros*, green; *phyllum*, a leaf) contained in the oblong and other shaped cells; in this respect these cells bear very close analogy to the color-producing or *pigment* (*paint*) cells of the human family, and other animals.

283. The dark color of the skin of a negro, or of an Indian, is

solely due to the secretion of color-cells, or pigment, in a certain layer of the skin; the human hair, and the hair of animals, depends for its color on a like secretion within the cells of the pith and cortical substance; and the *black*, or choroid coat of the eye, in man and animals, is solely composed of minute cells, filled with infinitesimal particles of a black paint.

FIG. 84.

Cherry leaf.

284. It is interesting to observe that the same law is in operation to give color to the leaf of a tree, and the skin, and other parts of a man.

285. It only remains to show the vascular system of a leaf, and for this purpose the leaf of a *cherry tree* is selected. Here the stalk (*petiole*) ends in a single mid-rib (Fig. 84, *a*, *a*); this gives off *primary* veins (*b*), which subdivide into secondary veins (*c*), curving within the margin.

LESSON XVII.

OF THE STEMS OF TREES.

286. The anatomical character of the stems of trees must now be considered. This structure consists of the elementary tissues, variously combined, and arranged in different ways.

287. In some plants the part which represents the stem is entirely composed of cells, which take the form of very narrow filaments; they are either simple or branched, as in some of the fungi and confervæ, or they form an expanded *thallus*, or frond (a term applied to the stem of certain plants, where the stalk and leaves are so intimately blended that they cannot be separated). In well formed, conspicuous stems, cellular and vascular tissue are both present.

288. Such stems always have as the basis of their structure a dense cellular parenchyma, in the midst of which is usually found fibro-vascular bundles, or fasciculi of woody fibres, with ducts of various kinds, and generally associated with spiral vessels.

289. It is in the mode of arrangement of these bundles, that the

important difference exists between the plants called *Endogenous* and *Exogenous;* for in the former, the bundles are dispersed throughout the whole diameter of the plant, without any particular plan, the intervals being filled by cellular tissue.

290. In the latter they are arranged side by side, so that a hollow cylinder of wood is formed, which includes within it the pith, whilst itself is enclosed in another (outer) layer—the bark.

291. But there is yet another and lower form of vegetable life—*Acrogens;* in these the bundles of vessels are simultaneously produced, and the additions to the stem take place at the summit, by the union of the bases of the leaves—tree-ferns afford an example.

292. Thus we have,

Acrogens (from *akros*, summit; *gennæin*, to produce), or *summit growers.*

Endogens (from *endon*, within), or *inside growers.*

Exogens (*exo*, outward), or *outside growers.*

293. But other and important distinctions still further define these three orders of plants, even in their earliest state. Thus, *Acrogens* have a cellular *embryo*, which has no *cotyledon* (Greek for *seed-lobe*); or, in other words, has no leafy appendages to the young plant; they are called therefore *Acotyledonous* (*a*, without). *Endogens* have an embryo with *one* cotyledon, and when sprouting send up a single seed-leaf; these therefore are called *Monocotyledonous* (*monos*, one). *Exogens* possess *two* such seed-lobes, or cotyledons, and are called *Dicotyledonous* (*dis*, two).

294. Consequently, Acrogens are Acotyledonous.
Endogens are Monocotyledonous.
Exogens are Dycotyledonous.

295. In all parts of the globe, Exogens are by far the most numerous of the Vegetable Kingdom; the forest trees of the World are Exogens, although in warm climates they are found associated alike with Endogens and Acrogens, which, in such climates, are more abundant, and attain greater size, than in more temperate regions.

296. In its external aspect the *Acrogenous* stem greatly resembles the *Endogens;* it is unbranched, usually of small, nearly uniform diameter, and produces leaves at its summit (Fig. 85).

297. The Tree Ferns, which furnish the best example of this kind of stem, are met with only in hot climates.

In India, they present a stem from six inches to eight inches in diameter, and attain a height of from fifty to sixty feet.

Fig. 85.

Tree Fern.

The foliage, consisting of leaves ten or twelve feet in length, is always produced at the summit; and, as the stem continues to grow, the leaves make an impression on it which becomes permanent, and adds greatly to its external beauty.

For the reason above given, this stem may be known at a glance; but, if a doubt exist, it will be immediately removed by examining its internal structure, as seen in transverse section.

Fig. 86.

Section of Tree fern, transverse.

298. A transverse section of an acrogenous stem (Fig. 86), shows a circle of vascular tissue composed of masses (*a*), of various forms and sizes, situated near the circumference; the centre (*b*) being either hollow or formed of cellular tissue. On the outside of the vascular circle, cells exist (*c*), covered by an epidermal layer (*e*), often of hard and dense consistence, originally formed by the bases of the leaves, which remain for a long time attached to the stem. The vascular masses (*a*) are bordered by dark-colored woody fibres (*f*); the pale-colored vessels, generally scalariform, which occupy the centres of the vascular masses, are shown at *g*. The vascular system is of greater density than the rest of the tissue, and is usually distinguished by the dark color of the layer which surrounds the paler vessels.

LESSON XVIII.

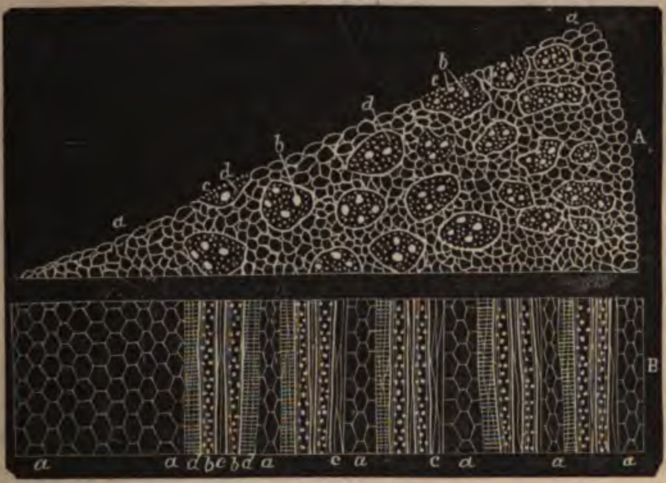
THE ENDOGENOUS STEM.

299. *Endogenous* stems have no separable bark; no distinct concentric circles; the vascular circles are progressive and definite, the solidity diminishing from the circumference to the centre; no distinct pith; no medullary sheath nor medullary rays; the cellular tissue being interposed between the vascular bundles.

300. For the full development of the Endogen we must seek hot climates,—there it is that its peculiar mode of growth is seen in perfection. The palms and screw pines offer the best examples; the former have simple, unbranched, cylindrical stems, attaining to a great height, and covered by a large mass of remarkable foliage.

301. The peculiar structure of this order of plants, will be best seen by reference to the accompanying figures; the first (Fig. 87, A),

FIG. 87.



Monocotyledonous stem.

is a transverse, and the second (B), a longitudinal section of the same stem; the letters in both refer to the like structures.

302. In its early state the Endogenous stem consists entirely of cellular tissue; but as it increases in age, vascular bundles are produced, and these consist of woody fibre, spiral, dotted, and lactiferous vessels.

303. The cellular tissue (a, a, a, a) is here seen distributed

throughout the section; from the outer layer of it, which represents the *bark* in the *Exogen*, to the internal portion which, in the same order, would be the *pith*—it is, in fact, only interrupted by the vascular bundles.

304. The dotted vessels are seen at *b, b, b, b; c, c, c, c*, are the woody fibres, and *d, d, d, d*, the spiral vessels.

305. From the peculiar mode of growth of the Endogenous stems they have perfect immunity from the effects resulting to Exogenous stems, of the parasitic plants which cling to, and climb around them.

306. In the Endogenous stem *the soft part is internal*, whereby the outer portion, from its greater density, is enabled to resist the pressure of the climber; but in the Exogenous stem *the soft wood is external*, and consequently yields to the least pressure, and climbing plants, therefore, make deep and permanent indentations in the latter.

307. Some Endogenous stems grow with such rapidity, that the sudden increase of the outer part occasions a rupture of the central cells, and by this means the hollow in the stems of grasses is produced.

308. The vascular bundles, in the *Bamboo*, cross the stem, and form a series of partitions which divide the cane, and give it a jointed appearance; between these partitions, however, the central cells have been ruptured, in the manner above alluded to.

LESSON XIX.

THE EXOGENOUS STEM.

309. Like the Endogenous, the Exogenous stem in its earliest condition is wholly *cellular*.

310. By degrees, and as the plant increases in age, the cellular tissue begins to be traversed by vascular bundles, which soon divide the stem into two marked portions; one of these forming the central *pith*, or *medulla;* and the other forming the cortical bark, covered with epidermis. The connection between these two portions (pith and bark) is maintained by lines of cellular tissue, called *medullary rays*, which are interposed between the vascular bundles.

311. The complete structure of mature exogenous stems, which

die down annually, consists of a *central cellular pith*, a *circle of vascular bundles* in the form of wedge-shaped masses, an *external bark*, with its integumentary covering, and *rays connecting the pith to the bark.*

312. In stems which are *not annual*, the growth of the second year consists of a new formation of vascular bundles outside the previously formed layer, between it and the bark.

313. Between the pith and bark also, there are annually formed a layer of active, formative cells, called *cambium cells*, which are concerned in the development of new woody fibres. In illustration a transverse section of the maple (Fig. 88, A) is shown, at the commencement of its second year's growth; a longitudinal section of the same plant (B) is combined with the former, and the letters of reference apply to the like tissue, in both sections.

Fig. 88.

Exogenous wood.—Maple.

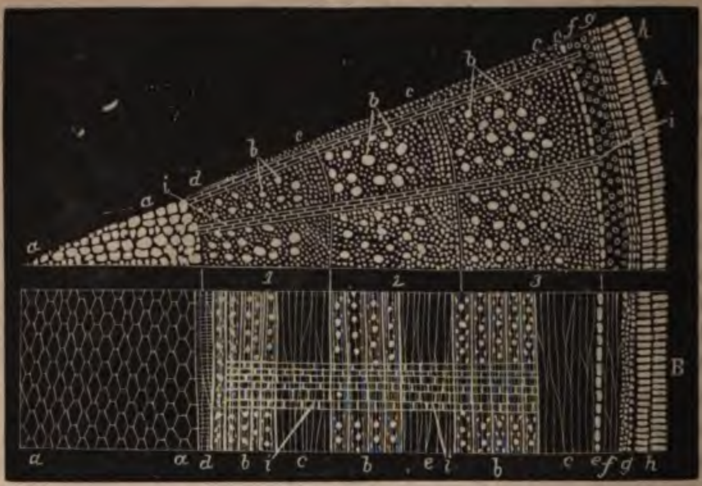
314. The layer of spiral vessels which surround the pith, and constitute what is called the *medullary sheath*, are seen at *a*; the medullary rays pass through this layer, at different points, to the bark; at *b* are the porous or pitted vessels, presenting (in A) large rounded openings; *c, c*, fibres formed of fusiform tubes, the letter to the right hand marking the fibres forming the wood of the stem, and the letter to the left, those which form the cortical fibres of the inner bark; *d*, cambium cells, between the wood and bark; *e, e*, cortical cells, often of a greenish color, forming a cellular layer of bark; *f*, outer cellular layer of bark, composed of cubical colorless cells, often of a *corky* nature, and hence called *suberous;* this cortical layer is covered by the general integument, or epidermis.

315. Thus, at the commencement of the second year's growth, there is a distinct formation of cambium cells, by the action of which a new layer of wood and a new layer of fibrous bark is formed, and these cambium cells, being in connection with the medullary rays, keep up the connection between the medullary and cortical cells.

316. It is exceedingly interesting and instructive to notice the changes that take place in the *permanent* woody stem of the exoge-

nous plant, after three years' growth; this is shown in Fig. 89. The yearly growth of the woody fibre is marked by the figures 1, 2, 3, and the same letters apply to like tissues in both figures, A being the transverse and B the longitudinal section. The pith, *a*, *a*, consisting of hexagonal cellular tissue, *b*, *b*, *b*, pitted or dotted vessels, and *c*, *c*, *c*, woody fibres of successive bark; *d*, *d*, spiral vessels of the medullary sheath; *e*, *e*, layer of cambium cells, between wood and bark; *f*, *f*, inner fibrous layer of bark, *g*, *g*, cellular envelope, forming middle layer of bark; *h*, *h*, outer corky layer of bark; *i*, *i*, medullary ray which, in the transverse section (A) is seen running without interruption from the pith to the bark; but in the logitudinal section (B) it

FIG. 89.



Exogenous, or Dicotyledonous wood.

is mutilated, owing to the slight flexure which usually occurs, and which generally prevents us from tracing the ray in an undivided straight line, when the stem is cut longitudinally.

317. Thus it will be found that the tissues have been produced in the following order: first year the pith, surrounded by spiral vessels, or medullary sheath, outside of which are the pitted vessels and fibrous tissue of the first year's growth.

318. In the second year, the pitted vessels succeed to the woody fibrous tissue of the first year, and these vessels are followed by the deposition of woody fibre, forming the second annual layer.

319. The third year commences with the formation of pitted ves-

sels, succeeded by woody fibre, as before; but now the bark must be formed: it has existed already twice before; but, when no longer required as such, its structure has become transformed into the woody fibrous tissue—in many Exogens, however, its elements remain permanently.

320. To the woody fibres, *cambium cells* succeed, then, the inner fibrous layer of the bark; next, the cellular envelope, which forms the middle layer of the bark; and, lastly, the outer corky layer, covered with epidermis.

321. It is only necessary, now, to describe briefly the characteristics of these tissues severally, by way of recapitulation, and firstly of—

322. *The wood.*—The layers of wood are formed outside the medullary sheath, or the vascular zone which surrounds the pith.

323. They consist of *woody fibres*, mixed with *dotted ducts*, occasionally mixed with annular, reticulated, and spiral vessels. In the young state the tubes of the woody tissue are pervious, but by degrees they fill up by the deposit of lignine within them.

324. In old, exogenous trees, the central wood is hard and durable, constituting the *Heart-wood*, while the external layer is soft, and forms the *Albernum* or *Sap-wood*.

325. The ligneous matter forming the heart-wood, of some trees, acquires color; thus it is black in the *Ebony*, brown in the *Black Walnut*, yellow in the *Barberry* and *Judas-tree*, purple in the *Red Cedar*, and green in the *Guaiac tree*.

326. The proportions between the heart-wood and alburnum differ greatly in different trees; those, however, in which the hard wood predominates are best suited for building, and better adapted to withstand the attacks of insects, or the wet or dry rot.

327. The durability of wood depends on the nature of the lignine, and this greatly varies in different trees.

LESSON XX.

THE REMAINING TISSUES.

328. *The Medullary Rays.*—These consist of flattened, cellular tissue, having the appearance of *bricks in a wall;* in the young stem

these rays are large, but in the more advanced woody stem, they appear as lines only. This tissue constitutes the "silver grain" of maple, and other trees, when cut in the direction from the pith to the bark.

329. They do not proceed in a continuous line, however, from the top to the bottom of the tree, but pass through the woody fibres in such a way as to be *interrupted* in their course.

330. The medullary rays in some plants (*Clematis*) are large and broad, while the woody wedges are comparatively small; in most exogenous plants these rays are *complete*, but in the *Cork-oak*, and others, they only extend partially through the stem.

331. *Cambium Layer.*—This layer is found between the wood and the bark, and has been originally connected with both.

332. It is composed of a layer of nucleated cells, formed in a mucilaginous fluid called *Cambium*, and they are concerned in the formation of the woody tubes of the inner bark, and in the additions made to the cells of the medullary rays.

333. In the Spring of the year, during the flow of the sap, these cells are actively engaged in the process of growth, at which time the bark may be easily separated from the wood.

334. *The Bark.*—Originally this tissue is composed of uniform cellular tissue, resembling that of the central part of the stem; transformations take place, however, in the progress of growth, by which fusiform (spindle shaped) tubes are formed in the inner portion of the bark next to the woody circle.

335. This portion is called the inner bark; it consists of woody fibre, and some lactiferous vessels; it is the *fibrous* part of the bark, and is frequently called *Bass*, or *Bast tissue.*

336. These fibres are long and tenacious, and are employed extensively for economic purposes; those of the *Lime-tree*, *Hemp*, *Nettle*, and *Daphne cannabina*, are employed for different articles of useful manufacture.

337. Sometimes the fibres separate, so as to form meshes, as in the *Lace-bark* tree; at other times they form a continuous layer, as in the *Horse-chestnut.*

338. The most remarkable fact in connection with woody fibre, is its immunity from decay; worn to rags, in an apparent state of thorough disintegration as *linen*, it is doomed again to meet our gaze in a new form as paper.

339. The value and importance of woody fibre, as applied to domestic manufactures, cannot be overrated, and appears to have been

known at a very early period of the world's history; thus we find that the ancient Egyptians were as well acquainted with the value and importance of flax, as employed in the construction of linen, as we are.

340. They used it expressly for this purpose, to the exclusion of every other vegetable tissue; the mummy-cloth, in which the bodies of the dead were enrolled, and of which such amazing quantities were used, no less for the mummified remains of cats, the Ibis, bullocks' heads, &c., than for the needs of poor humanity, was composed entirely of *flax*. If the deceased person chanced to be a King, or a Priestess (probably, also, any very distinguished person), a layer of beautifully "*fine linen*" was placed next to the body.

341. Belzoni, the celebrated Egyptian traveller, brought to England, and placed in the British Museum, the Sarcophagus, containing the body of a King, exhumed from the tomb of the ancient Kings of Thebes. The Sarcophagus was in the last stage of decay, but the *vegetable papyrus*, which recorded the rank of the deceased, and the date of his demise, together with the several layers of mummy cloth, were as perfect as though made yesterday! And yet this body had lain in the tomb *upwards of five thousand years!*

342. But a still older mummy may be seen in the Muesum of the Vatican at Rome; the individual is admitted to have lived contemporaneously with the Patriarch Abraham—yet the mummy cloth is by no means decayed!

343. These facts are well known to persons possessing Microscopes, and curious in such matters, who have had no difficulty in procuring specimens for examination.* We have seen that the layer placed next to the body was of fine texture, and free from bitumen; the layer which succeeded this was somewhat coarser, and imbued with bitumen (mineral pitch) slightly. Of the remaining layers, each one was coarser than that which preceded it, till the outer layer was remarkably coarse, strong, and close in texture. The bitumen increased with the coarseness of the cloth, so that the outer layers were perfectly saturated with it.

344. If the Egyptians constructed their mummy cloth of *flax*, the ancient Peruvians, who also embalmed their dead, invariably employed *cotton* for this purpose, and the only mode of discriminating between Peruvian and Egyptian mummy cloth, is by submitting them to the Microscope.

* The author has many such examples in his possession, ranging from 2,000 to 5,000 years old.

345. The woody fibre of flax and hemp is chiefly employed by us for economic purposes; in the Philippine Islands the fibre from the leaves of a plaintain is used; in Mexico the leaves of some wild species of pine-apple furnish a similar substance; an endless variety of plants are used for cordage, for almost every country applies its own plants to this purpose.

346. Our obligations to woody fibre are infinite; without its aid we might forego the luxury of a shirt to our back, sails and cordage for our ships, or a door-mat upon which to clean our shoes; without its assistance this book could not have had existence, for the paper upon which it is printed, and the wood upon which the engravings have been made, are—woody fibre.

PART II.

ANIMAL PHYSIOLOGY.

LESSON XXI.

THE ORIGINAL COMPOUNDS OF THE ANIMAL BODY.

347. The egg of an Oviporous (egg-laying) animal, is found to consist of two parts—the yelk, and the white, as it is called. The yelk is incapable of forming a tissue, and is destined to be entirely converted, by the process of incubation, into cells. The white is known to chemists by another name, that of albumen, and this is found to be the most universal and important constituent of organized beings.

348. Albumen, through the aid of a series of chemical and vital processes, becomes *nerve*, *muscle*, *tendon*, *ligament*, *membrane*, *areolar tissue*, *horny substance*, *feathers*, *the animal portion of bone*, *&c.*

349. These remarkable changes are not confined to the embryo, or the young condition of an animal, for, on the contrary, they are constantly taking place through all the phases of adult life. By the wonderful chemistry of digestion, all substances of similar composition are reduced to albumen, which forms an essential part of the fluids absorbed for the nourishment of the tissues.

350. When Gelatine (calves-foot jelly) is consumed as food, there is little doubt that it becomes associated with the general circulation, but the doctrine of Chemical affinity appears to prevail in the organization of tissues—like joins like—so that on this principle the gelatine goes to where it belongs—to the gelatinous tissues—the *bones* and *teeth*.

351. Nerves, muscles, ligaments, tendons, are *not* gelatinous; this element forms no part of their structure, and consequently the capillaries belonging to these tissues respectively, refuse to recognize its presence, and pass it on.

352. Albumen exists in a soluble state in animal fluids; it may be easily dissolved in water, when it forms a glairy, colorless, and almost tasteless fluid. In this state, however, it is always found combined with a minute quantity of free Soda; hence it is supposed that *pure* Albumen is *insoluble in water*, and requires the assistance of an alkali. Whether in its soluble or insoluble state, albumen always contains a small portion of *sulphur*, which blackens silver; for this reason a silver spoon is made black at the breakfast table, when eggs are present, and to avoid this contingency many persons prefer to use a bone, or ivory spoon, with eggs.

353. Albumen shows no disposition to become organized, or to form tissues; but after its introduction into the body of a living animal, it *changes* into another compound, having new and peculiar properties, called *Fibrine.*

354. According to the analysis of Dumas, the ultimate composition of Fibrine, and Albumen, shows that the former contains less Carbon, and more Nitrogen, than the latter; the chemical composition of these elements does not appear to be of much account, as the transformation of Albumen into Fibrine is much more a vital than a chemical process.

355. Like Albumen, Fibrine may exist in a soluble, or in a coagulated state; but it is only found soluble in living animal fluids, as the Chyle, Lymph, and Blood. When withdrawn from the blood-vessels, the Blood soon coagulates, as do also the Chyle and Lymph; this coagulation is due to a change in the condition of the Fibrine, the particles of which have a tendency to aggregation in a definite and peculiar manner. This process is called *fibrillation*, which seems to be allied to crystallization.

356. A single fact will suffice to show the close chemical relation subsisting between Albumen and Fibrine, that from both of these (no less than from many vegetable substances used for food) a similar substance may be obtained by a simple process.

357. If boiled Albumen be dissolved in a weak solution of caustic alkali, and the liquid be neutralized by an acid, a precipitate falls down in grayish white flocks; this being collected and washed, is gelatinous, of a grayish color, and semi-transparent; and when dried, it is yellowish, hard, easily pulverized, tasteless, insoluble in water

and alcohol, and decomposes by heat without fusing: this substance has been called *Proteine*, from an idea that it is the first and fundamental principle of which Albumen, Fibrine, &c., are but modifications. It contains the same proportions of Carbon, Hydrogen, Oxygen, and Nitrogen, as Albumen and Fibrine; but it is destitute of Sulphur and Phosphorus; Liebig, however, doubts the latter assertion.

358. Albumen shows no tendency to coagulate, except by the aid of chemical influences, and its coagulum is devoid of structure. Fibrine exhibits a constant tendency to form solid tissues, and it appears only to be kept in check by the operation of influences not understood. It is highly probable that the production of tumors, and morbid growths, in the interior of the body, no less than upon its external surface, owe their origin to the persevering tendency of Fibrine to form tissues; exhibited at a period when the law (whatever it may be) that should govern it, is in abeyance. Certain it is that a great number of adventitious (accidental, extrinsic) growths when microscopically examined, consist only of *fibrillated fibrine*.

359. The conversion of Albumen into Fibrine may be regarded as the *first great step in the process of nutrition;* the mode by which the varied materials used for food, are made to form a part of the tissues of the living body.

360. Fibrine first makes its appearance in the Chyle—the fluid found in the Lacteals (*lacta*, milk); *Chyle* is the immediate product of digestion, and will be more fully explained hereafter.

361. The proportion of Fibrine in the blood, as indicated by the firmness of its coagulum, is much greater than that contained in the Chyle, and in certain conditions of the blood, resulting from disease, the proportion of fibrine is increased to twice, thrice, or even four times its usual amount.

362. In the process by which injuries to parts are repaired, there is an exudation of fibrine; this is said to form plastic, or coagulable lymph.

363. In exudation, the *liquor sanguinis* (fluid portion of the blood) is alone poured out, and this fluid holds the fibrine in solution; the solid portion (red corpuscles) takes no share in this process of reparation.

364. When describing the *latex* in plants, a comparison was instituted between its properties and the properties of the blood in animals, particularly in relation to its ability to form tissues by a process of coagulation.

It was to this particular principle of exudation of the plastic lymph, whereby a new tissue may be formed without the agency of development by cells, that the comparison was intended to apply.

365. Examined by the microscope, it will be seen that the usual mode by which tissues are constructed out of fibrine, consists in a tissue of densely matted fibres, which cross each other in every possible direction; this can be well seen in the *Crassamentum*, or clot (the solid, colored portion) of human blood, or of the blood of any other animal. The clot should be hardened by boiling, and thin slices of it made with a sharp razor; the fibres (fibrillated) of fibrine will be clearly seen, and in their meshes, or interstices, the red corpuscles. The arrangement, however, of the fibrine is still better seen in the *Buffy coat*, or fluid portion of the blood which arises above the surface of the clot.

366. This mode of tissue forming is not limited to the process of repair; there are certain distinct tissues in the Animal Kingdom, always, and alone formed on this principle.

If the Hen's egg be boiled moderately hard, the white will display a tough, semi-transparent membrane in which it is enclosed, and which separates it from the shell: it is called *Membrana putaminis.*

367. If this membrane be macerated in water for a few days, it may then be separated into layers—many of which will be found to enter into its composition;—examine *one* layer by the microscope, and an appearance will present itself like Fig. 90. Now drop a piece of the shell into Acetic Acid, which will quickly remove the Carbonate of lime, with which the animal membrane has been consolidated; examine this membrane with the microscope, and it will then appear that the animal basis of the egg shell is a simple matted tissue of fibrillated fibrine, offering its meshes as receptacles for the deposition of the mineral matter.

FIG. 90.

Membrana putaminis.

Here, then, is an animal membrane destitute of blood-vessels, and wholly formed by the consolidation of Fibrinous elements.

368. Wounds that are said to heal (in surgical language) by "the first intention," are really knit together by the plasticity of the coagulable lymph, as the liquor sanguinis of the blood is called; in other words, lymph is thrown out from each lip of the wound, and extending across to, and joining the other lip, the lymph *fibrillates*

(forms fibres), by which process the lips (say a cut finger) are brought together, and permanently laced by the newly formed fibres. In this operation lymph is thrown out in excess, and the portion of it that cannot be used, dries up, by exposure to the atmosphere, and is invariably of a yellowish color—never red—thereby showing the absence of the red corpuscles in this process.

LESSON XXII.

OF CELLS, MEMBRANE, AND FIBRE.

369. The history of the vegetable cell has already been given; the history of the animal cell is in every respect precisely similar. So perfectly identical is the cellular tissue of a plant, and an animal cellular tissue, that the microscope fails to detect a point of difference; when, too, we consider the number of diverse animal tissues having a cell-structure for their basis, this fact is not a little remarkable.

Still, there are important differences between them, which the Chemist can detect, although the microscope in this respect is powerless.

370. We have seen that the cell-wall of a plant is composed of *cellulose;* the animal cell-wall is equally transparent, and possesses all the other microscopical characteristics, but it is chemically different; every animal cell-wall is solely composed of an animal element, namely, *Proteine.*

371. Great difference exists in the contents of animal cells; thus the cells which float in the *Chyle*, the *Lymph*, and the *Blood*, the latter devoid of color, have no *single nucleus*, but a variable number of scattered particles in the nature of nucleoli (little nuclei), each of which obtains an independent existence by the bursting or absorption of the cell-wall: here, again, is a vegetable parallelism.

372. The liberated nucleoli float in the fluid, till they, in their turn, mature into perfect cells.

In animal, as in vegetable cells, the nucleus appears to be the all-important portion of it; the membrane appears to have little else to do than simply containing and isolating it.

373. In many animal tissues the multiplication of the cells can

be distinctly traced to the spontaneous division of the nucleus, as in plants.

374. A good example of this fact is met with in the development of Cartilage; if we examine *young* Cartilage (or the Cartilage of young animals), where the tissue is in a state of active formation, groups of cells will be found, the nucleus sometimes entire, sometimes just divided, and other examples in which division and subdivision (into four parts) have taken place (Fig. 91); the primary cells (*a*) contain an entire nucleus; the secondary cells (*b*) show the division into four nucleoli, while the remainder of the cells simply demonstrate division.

Fig. 91.

Cephalic cartilage, Tadpole.

SIMPLE FIBROUS TISSUES.

375. All animals possess a very large amount of what has been improperly called *Cellular tissue;* this term is now restricted, however, to those tissues which are found to consist of a congeries of cells, and the word *Areolar* has been proposed (and adopted) in place of Cellular tissue.

Examined by the microscope this tissue is found to consist of a net-work of minute fibres and bands, interwoven in every possible direction, leaving innumerable interspaces communicating with each other. When a butcher kills a calf, he makes a small hole in the skin, applies his mouth, and blows into it; by this means he distends the whole body, because he has inflated the areolar tissue. If the human body, the body of a dog, or of any other animal, be allowed to remain in the water after death, gas is generated as the result of incipient decomposition; it fills the meshes of the areolar tissue, and distends the body enormously; as a consequence of its great buoyancy it is enabled to float on the surface of the water.

376. The fibres which enter into the composition of Areolar tissue, designate two other distinct tissues, i. e., the *white fibrous* and the *yellow fibrous tissues;* both of these have an independent existence, however, in other parts of the body.

377. Thus the white fibrous tissue exists alone in Ligaments, Tendons, Fibrous Membranes, &c., where it presents precisely the

same characters as when it is found associated with the yellow element to form areolar tissue.

The yellow fibrous tissue exists separately in the middle coat of the arteries, the Chordæ vocales (vocal cords), the Ligamentum

FIG. 92.

White Fibrous Tissue.

FIG. 93.

White and Yellow Fibrous Tissues.

nuchæ (or suspensory ligament, which supports the head), of quadrupeds.

378. The white, called also the inelastic fibrous tissue, consists of bands (Fig. 92) which run parallel with each other, and form a series of wavy lines; they appear to be composed of a number of

FIG. 94.

Yellow Fibrous Tissue.

FIG. 95.

Ligamentum nuchæ. Ox.

component fibres; it is not so, however, since no manipulation can succeed in separating them. Areolar tissue from many parts of the

body is found to be composed of the two elements; that is to say, of the white and yellow fibrous tissues. If the areolar, or cellular tissue, beneath the pectoralis major muscle (large muscle of the chest) be examined, microscopically, these elements will be seen as clearly as in the subjoined figure (Fig. 93) obtained from this situation; *a* shows the white and *b* the yellow fibrous tissue.

FIG. 96.

Transverse section, Ligamentum nuchæ.

379. The yellow, or elastic fibre, exists as long, branched filaments, with a dark border, and always curling when not put on the stretch (Fig. 94).

380. This tissue is seen in great perfection in the strong *Ligamentum nuchæ* of the Ox (Fig. 95), and its tendency to curl at the ends is well marked; a transverse section of the same tissue is shown at Fig. 96.

LESSON XXIII.

SIMPLE CELLS, FLOATING IN ANIMAL FLUID.

381. If the human blood be examined by the Microscope, or, still better, the circulation of the blood in the web of the Frog's foot, a great number of distinct bodies, or cells, will be seen floating in an invisible fluid. The cells are the red corpuscles, characteristic of the blood in all the red-blooded animals; the fluid in which they float is the liquor sanguinis.

382. The red corpuscles have been called "globules"—an improper name because untrue. Their figure differs in various animals, but they are not *globular* in any. In man, and the mammalia, they are flattened discs, slightly concave on both sides; in all the Oviparous (egg-bearing) vertebrata, they are oval, and of much greater size than in the mammals, or man.

383. That the corpuscles are very elastic is proved by the alteration of figure which they undergo in passing through narrow capillary blood-vessels, particularly when passing the bent, or rounded part of the vessel; as soon as they have more room, they instantly recover their original figure.

384. The size of the corpuscles not only greatly differs in various animals, but even in the same individual—some being met with as

much as a third larger or smaller than the average. The size of the animal offers no criterion for the size of the blood corpuscle, although it is true that they are largest in the elephant of all the mammalia, he being, at the same time, the largest mammal; but the pigmy mouse tribe (Fig. 107) possesses corpuscles many times larger than those of the musk deer (*Moschus Javanicus*).

385. Much controversy has existed amongst microscopists as to whether the human blood discs contain a nucleus or not. Reasoning from analogy they ought to possess a nucleus, and many observers have a firm conviction that they can plainly detect it. In all the Ovipara it certainly exists, and can be rendered apparent by dissolving the external envelope and setting the nucleus free. A representation of the corpuscles of human blood is given (Fig. 97); the preparation from which the drawing was made is dry, and it can be placed in focus, so as to show a very distinct, red colored nucleus (*a*). Those who deny the presence of a nucleus, attribute the effect of color to refraction.

FIG. 97.

Human Blood Corpuscles.

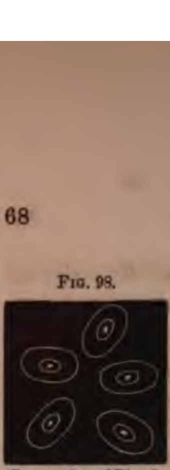
386. The membrane which forms the cell-wall of the corpuscle is readily permeable by fluids, and under their influence its form is easily altered; treated with water, the liquid readily passes into the cell; firstly the disc becomes flat, then double convex, so that all trace of the nucleated spot is lost; afterwards it becomes globular, and in the end it bursts—the contents (whatever they may be) escaping. But if treated with a thick syrup, or albumen in solution, their contents will pass out, and the cell-wall assume a shrivelled appearance; the first effect of this treatment is to increase the concavity, and render the central spot more conspicuous.

387. It has been stated that the size of the human red corpuscle varies, and according to accurate measurements it appears to range from the 1-4,000th to the 1-2,800th of an inch; probably the average is about the 1-3,200th.

388. When inflammatory action exists, the red corpuscles have a great tendency to aggregate and form *rouleau* (*b*, Fig. 97); this condition is so certain that frequently when fingers have been pricked to show the blood obtained, to a party of assembled guests, one of them has thus demonstrated the presence of slight inflammatory action.

389. From a series of experiments made upon the frog's blood, the corpuscles of which are shown in Fig. 98, it appears that the nu-

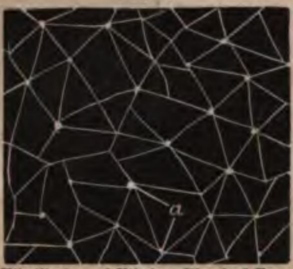
FIG. 98.



Corpuscles of Blood, Frog.

cleus consists wholly of Fibrine; the blood of a frog was placed upon a slip of glass, and slightly diluted with water; in due time the cell membrane dissolved, and liberated the nuclei. These maintained their integrity for a time, but in the end began, insensibly, to dissolve. They firstly became completely spherical, and shortly afterwards, the sphere simultaneously diminishing, and the water evaporating, a number of radii suddenly shot out from all that remained of the nuclei, and this process continued until the water had completely evaporated. The dried preparation being examined, disclosed fibrillation of fibrine emanating from the nuclei respectively; but the water being insufficient to complete their entire resolution, portions of the majority of the nuclei remained, and are still permanent (Fig. 99). This experiment was re-

FIG. 99.



Fibrillation of Fibrine, Blood of Frog.

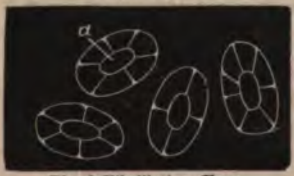
FIG. 100.

Fibrillated Blood of Locust.

peated several times, with the like uniform results, and six preparations exist to confirm these facts. In every instance the *cell-wall* appeared to dissolve entirely, and exhibited no tendency to fibrillate; moreover, the fibres of fibrine are, in every instance, distinctly seen emanating from all that remains of the nuclei.

390. The same experiment was made on the blood of a locust, with precisely the like results (Fig. 100). Here some of the blood corpuscles are (comparatively) large (*a*), while others are minute (*b*); fat or oil globules are also seen at *c*. So great is the disposition for blood to fibrillate when drawn from the body, that the nuclei of the frog's blood very frequently throws out fibres of fibrine, within the cell-wall, as illustrated

FIG. 101.



Blood Fibrillating Frog.

in Fig. 101. This illustration has been magnified with an eighth object glass, to give greater size and distinctness to the figure. The nuclei (*a*) will be clearly seen within the cells, and the fibres of fibrine range from four to seven in number; in every instance they can be seen to be pulled out, as it were, from the nuclei. This has been seen before by Prof. Owen, but misinterpreted (if the above facts be true); the Professor believed that the lines indicated a puckering of the cell-wall.

391. If these observations can be depended on, and they require confirmation by another experimenter, there seems to be great reason to believe that the human corpuscle contains a nucleus, and that its element is chiefly fibrine. That the fibres of fibrine, in the experiments alluded to, really arose from the nuclei, and not from the colorless corpuscles, is rendered certain by the fact that all that remains of them retains the red color distinctly; the nuclei, as will be seen by reference to the figure, are of all sizes—some moderately large, others quite minute.

About an hour after a mosquito had made a meal, it was killed, and the human blood contained in its crop and stomach examined by the microscope. The nuclei (real or apparent) had disappeared, leaving only a faint ring (Fig. 102) to mark its place.

Fig. 102.

Fig. 103.

Human blood corpuscles, from stomach of Mosquito.

Another mosquito was killed three or four hours after a meal; in this instance, neither nuclei nor rings could be discovered (Fig. 103); but in both instances the corpuscles retained their full size—apparently uninjured by the action of the digestive process. These experiments were repeated several times, with the same uniform results, and the preparations exist to confirm the accuracy of the experiments.

The inference appears to be that the human blood corpuscle does contain a nucleus; that its structure differs from that of the cell-wall, and that it is far more accessible to the action of the saliva and the gastric juice than the latter, which remains intact long after the former has disappeared.

392. The shape of the human blood corpuscle is discoidal; so too in the mammalia; in the birds, reptiles, and fishes, it attains much greater size, and is more or less oval or oblong in shape, as may be seen in the blood of the common fowl (Fig. 104). It has been said that the ostrich possesses the largest red corpuscle of all the warm-

blooded animals; but the subjoined figure of the ostrich blood (Fig. 105), accurately copied from the preparation, and carefully drawn to scale, tends to disprove this assertion, as the corpuscles of the fowl, both preparations being examined by a fourth object glass, are certainly larger.

FIG. 104.

Blood corpuscles, Fowl.

FIG. 105.

Blood corpuscles, Ostrich.

If the ostrich has borne the reputation of possessing the largest, there can be no doubt that the beautiful little Musk Deer possesses the smallest blood corpuscles of all the warm-blooded animals.

Magnified by a fourth object glass, they are but infinitesimal specks (Fig. 106); for comparison, the blood of the mouse is shown (Fig. 107).

393. In addition to the red corpuscle, all the vertebrate animals possess also a colorless corpuscle (Fig. 108), which is uniformly round, and possesses a variable number of granular bodies, or nucleoli.

These bodies may be seen (in the frog's foot) in the same vessels with the red corpuscles; they are very sluggish, apparently possess-

FIG. 106.

Blood corpuscles, Musk Deer.

FIG. 107.

Blood corpuscles, Mouse.

FIG. 108.

Colorless corpuscles, human.

ing greater specific gravity than the red corpuscles; they cling to the sides of the vessels, and only move when struck against by the red corpuscles. Occasionally it happens that a red corpuscle strikes a colorless one up into the general current of the circulation, where it circulates for a longer period than usual; but as soon as the impetus of the blow begins to fail, it drops out (apparently by its own weight), and once more clings to the sides of the vessel.

394. The origin of the colorless corpuscle appears to be the following: the liquor sanguinis receives constant fresh accessions of albumen and fibrine, the result of the digestion of the food. This has a tendency to alter the *specific gravity of that fluid* (liq. sanguinis): if this were to take place, and the density of the fluid become too great, the blood corpuscles (red) would scarcely be able to move; but if, on the other hand, it became too light, the red corpus-

cles would flow at a rapid rate, and simulate fever. These conditions of the blood really occur under the influence of disease; in a state of health it appears to be imperative that the liquor sanguinis maintain a certain specific gravity, but still the weighty elements pour in! What is now to be done?

To relieve this state of things it seems probable that the excess of albumen and fibrine is rolled up, in the solid form, to get it out of the way, and thus the specific gravity of the fluid is maintained.

395. The observations, particularly of Mr. Paget, lead to the conclusion that these colorless corpuscles gradually change into the red corpuscles, and if this theory be correct, the whole phenomena of their development is remarkably simple and beautiful. Firstly, the colorless corpuscle, formed out of the excess of the materials held in solution in the liquor sanguinis, takes on the solid form, in which it is no longer soluble; and secondly, the series of gradual changes by which it becomes transformed, with new characteristics, into the red corpuscle. Mr. Paget's observations regarding the origin of the red corpuscle, confirm the experiments on the frog's blood, in regard to the fibrinous character of the nucleus, and offer an additional reason for believing that this body should and does exist in human blood.

396. The colorless corpuscles appear to possess great power to repair injuries. If the web of the frog's foot be artificially inflamed under the microscope, the colorless corpuscles will be seen to rush in considerable quantity from all adjacent parts, to the seat of injury, and there they remain till the disease disappear.

If a boil, or other inflamed surface in the human subject, be pricked with a needle, and the fluid thus procured be examined with a microscope, it will appear to be almost composed of the colorless corpuscles, thus demonstrating their activity to cure disease.

LESSON XXIV.

CELLS DEVELOPED UPON FREE SURFACES OF THE BODY.

397. A great difference exists between the cells forming the external surface of the body, *Epidermis* (*epi*, upon; *derma*, skin), or the cellular covering of the external surface; and the *Epithelium*, or the cellular covering of the internal mucous membrane.

FIG. 109.

Scales of human epidermis.

398. The Epidermis consists of several layers, produced by and forming the external surface of the cuticle; the external one being a series of horny, transparent, flattened, scale-like cells (Fig. 109), the lower layers of this tissue possess the true cellular character. The outer layers are continually being exfoliated, or thrown off, and are as constantly being reproduced below. The preservation of a healthy skin demands the removal of the entire epidermic layer, by frequent ablution, always accompanied by the liberal use of that valuable detergent—soap.

399. For the strict purposes of health, neither a plunge nor shower bath is necessary—the latter is even obnoxious to some temperaments: the most comfortable and healthful form of bath is at the same time the most facile—a sponge bath—expedition in its use being the most important element.

The bath itself should never exceed five minutes; the rubbing dry (the most essential part of the process) occupying another five minutes or more—an amount of time that every one can afford at the beginning of the day. This bath should be taken immediately on rising in the morning, as at such time reaction is greater and quicker than at any other period of the twenty-four hours.

It is very necessary to attend to the temperature of the water, and of the room in which the bath is taken. During hot summer weather, water may be used at the ordinary temperature of the atmosphere, the room indicating not less than 70° Fahrenheit. But at a less external heat than 70° the water should be warm, or at least tepid.

400. A sudden cold chill on the surface of the body is prejudicial to health; it checks the circulation of the blood to the external surface, interferes with the secretions, and particularly arrests the excreting power of the skin.

401. It is a popular belief with mothers, that washing young children daily, in cold water, makes them hardy. This is a grave mistake; the feeble circulation of a child requires the aid and assistance of warmth—warm water and warm clothing. The greatest medical man who ever lived—John Hunter—recommended three rules for the management of children, and they express the substance of a volume; he says, "give them plenty of milk, plenty of sleep, and plenty of flannel."

402. In this changeable climate, children and females are too thinly clad, and the great mortality amongst females is mainly due to this cause; they are so much exposed to external influences that they

are unable to maintain a sufficient degree of vital heat, hence, all their functions are indifferently performed; they sicken and die. Many females, of all ages, and even in the depth of winter, cover the upper part of the body with but two garments, whilst the hips are covered with an excess of clothing. Now it happens that the chest and body, which are unclothed, contain all the important organs of life, and special care should be taken to preserve them.

403. European women, remarkable for their robust health, all wear corsets, the substance of which, in addition to other appliances (stay-bones), gives alike great support and warmth to the body. Moreover, they greatly improve the figure, and render the set and fit of a dress perfect. It seems a pity that because a few silly, thoughtless girls would persist in destroying themselves by tight lacing, that such a very useful and necessary garment should be discarded. The practice of wearing so many clothes upon the hips is highly reprehensible, as it originates disease of a serious and distressful character.

404. If it be deemed essential to protect the lower portion of the body with such a great accumulation of dress, each garment ought to be suspended from the shoulders by means of straps, unless a corset be worn; but if a corset be not employed, it would be preferable, on the score of health, to provide each article with a body; in either case the weight would be removed from the hips.

405. After bathing a child and wiping its body quite dry, friction all over the surface, and especially of the limbs and down the spine, with the palm of the hand, in the nature of good, brisk, quick rubbing, should be practised till the surface be red—indicative of reaction; after this envelope the body in flannel.

406. For adults to bathe after a meal, or after fatiguing exercise, is eminently dangerous. Three fatal cases were recorded by the New York papers, all occurring within a year, from this sole cause; the first was the death of an American lady of refinement and position, from taking a bath soon after dinner; of Sergeant Hume, while alone in a warm bath, and of Lorenzo Shepherd, of New York, under precisely similar circumstances.

407. Those persons who do not happen to possess a sponge, may resort to the following plan with great advantage: as soon as you get out of bed in the morning, wash your hands, face, and neck; then, in the same basin of water, put your feet at once for about half a minute, rubbing them briskly at the time; then, with the towel that has been dampened by wiping the face, feet, &c., rub your whole body well (without the addition of more water), fast, and hard, mouth shut, and the breast projecting. Allow five minutes for this operation.

408. There is yet another plan, superior in some of its effects to all that has preceded it; at night, when you go to bed, and whenever you get out of bed during the night, spend from two to five minutes rubbing your whole body and limbs with your hands, as far as you can reach in every direction; let it be done briskly, quickly, and hard. By this practice the softness and mobility of the skin will be preserved, which too frequent washings has a tendency to destroy.

409. The cuticle has neither nerves nor blood-vessels, but it is abundantly pierced by the evacuating ducts of the sebaceous (fatty) and sudoriferous (sweat) glands, and also by the shafts of the hairs.

410. It appears to be developed for the sole purpose of protecting the layer beneath it—the true skin.

411. If the cuticle be accidentally removed, the true skin suffers acute pain from exposure to the air, and change of temperature. In addition to the cells of the epidermis whose function it is to secrete horn, there are other cells secreting only pigment (paint); in the white races of mankind these cells are easily distinguished, but they are most apparent in the colored races. There appears to be great relation subsisting between the development of pigment cells in man, and exposure to light, that is to say, the greater the light, the more the color. It is under circumstances of intense *heat* and *light*, that the negro, the red Indian, and all the varieties of the colored races of mankind, are produced and flourish. In this respect the analogy with plants is no less perfect than admirable.

LESSON XXV.

THE NAILS.

412. May be regarded as an altered, transformed, or modified epidermis; they consist of two layers—a soft mucous and the horny layer, or true nail.

413. The *bed*, or *matrix* of the nail, corresponds with it accurately in size and form. If the nail be removed by maceration, its anterior (front) and middle portions are divested of epidermis, and become uncovered; the lateral portions, or *edges*, and the posterior portion (back part) are invested by a part of the cutis. This will be best understood by consulting the accompanying figure (Fig. 110), which gives a view of a transverse section of a nail, made through the body and bed of it. The bed of the nail (with black ridges) is

shown at *a*, the corium and lateral parts at *b*, the stratum, first described by Malpighi, and called by his name, with white ridges, at *c*; horny layer, on the wall of the nail, *e*; horny layer, or proper nail substance, *f*—with short notches upon its under surface, *d*.

FIG. 110.

Transverse section, through the body and bed of the Nail.

414. The Malpighian layer of the nail, like that of the epidermis, consists wholly of nucleated cells, and agrees in all essential points with it, except that the deep portion contains a series of large perpendicular cells. In the negro, the Malpighian layer of the nail is black, and its cells even appear to contain dark brown nuclei, as well as yellowish brown ones in dark Europeans. An enlarged view of a transverse section through the body of the nail (Fig. 111), will better explain these facts. A, represents the cutis (true skin) of the bed of the nail; B, Malpighian layer; C, horny layer, or proper nail substance; *a*, layers of the bed of the nail; *b*, white ridges of the Malpighian layer; *c*, ridges of the horny layer of the nail; *d*, deepest perpendicular cells of the Malpighian layer; *e*, its upper series of flat cells; *f*, nuclei of the horny layer.

FIG. 111.

Transverse section through the body of a Nail.

415. The structure of the horny layer can only be ascertained by the aid of reagents; thus, boiled in *dilute* caustic soda, it appears in the form of beautifully definite nucleated cells (Fig. 112); the distended membrane of the cells is shown at *a*, and the nuclei at *b*.

FIG. 112.

Nail plates from the surface, boiled in Caustic Soda.

416. The vascularity of the bed, or matrix of the nail, is an object of great interest; these vessels differ entirely in their form, arrangement and size, from the capillaries of the cutis vera (true skin), as may be seen by reference to Fig. 113. The capillaries of this tissue are remarkable for their extreme fineness and parallelism; their function appears to be to secrete the horny layer, which forms the true substance of the nail. The vessels of the *cutis vera* (true skin) everywhere surround the vessels of the matrix, the terminal looped capillaries of the papillæ of the skin being distinctly visible.

417. In that horribly severe and excruciating operation of what is called minor surgery (!), the removal of a nail because its edges grow inwards, and produce great pain, associated with constant irritation, the unfortunate patient frequently desires to know "if the nail will grow again." The answer to this anxious question is generally very vague, "sometimes it does, and sometimes it does not." A little practical physiology would enable the operator to give a positive answer—"It shall either grow again, or not, at your pleasure." If the peculiar stratum of vessels just examined be included in the operation, the nail can never grow again, as the vessels which produce it are gone, and there is no power in the human subject (or higher mammals) to reproduce lost parts:—they, therefore, once removed, can never be replaced, and their function is gone.

Fig. 113.

Vessels of the Matrix of the Nail.

418. It appears to be bad surgery, however, to remove an entire nail for the fault of its edges; they alone should be removed, care being taken to include these particular vessels, with the offending portion of the nail.

419. The horny hoofs of horses, sheep, oxen, pigs, &c., are all formed by a similar layer of vessels, which, when minutely injected and well displayed, form objects of exceeding beauty, particularly the vascular lamellæ of the Horse's hoof, which is intended to act as a series of beautifully elastic springs. Notwithstanding the exquisite sensibility of this especial vascular layer, the terminal loops of the nerves have hitherto escaped detection.

LESSON XXVI.

HAIR.

420. Hair, in its origin, is an epidermic tissue, and is formed out of cells; but by the time it has acquired its full development, it has become so completely modified that all trace of its origin is lost, and can only be reclaimed by the judicious application of re-agents. The hair originates within a follicle (a little bag), which is formed by a depression of the skin, and lined by a continuation of the Epidermic layer. From the bottom of this follicle there arises a cluster of cells, which are *Epidermic cells;* the exterior of this cluster is the *bulb*, and the soft interior portion is the *pulp*. Although the follicle is extremely vascular, and even the bulb becomes reddened by minute injection, yet no vessels have yet been traced to the interior of the hair. The hairs of most animals present three elementary parts—an external *cuticle*, the *cortical*, *horny*, or fibrous substance, and an internal *medulla* or *pith ;* these elements attain their highest development in the quills, or modified hairs of the porcupine, and the English hedgehog (*Erinaceus Europæus*).

Two of the three layers above indicated, may be distinguished in all hairs, without any exception—the cortical, and the medullary : the cuticular covering is sometimes wanting.

421. The cortical, or fibrous substance of a hair is longitudinally striated (Fig. 114); it often presents dark spots, except in white hairs (in which it is transparent), and is more or less deeply colored. The color is sometimes distributed with tolerable regularity, and sometimes more concentrated in granular spots.

FIG. 114.

Striated appearance of the Cortical substance, Human hair.

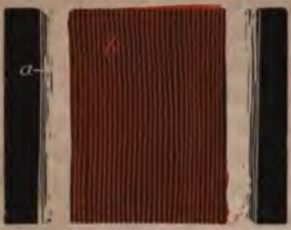
422. The medullary substance, or pith, is composed of an aggregation of very large cells, which do not possess fluid contents in that part of the hair that is completely formed, but it is filled with cells, usually containing pigment.

423. The feathers of Birds are precisely analogous to the hair of animals; the cortical (horny) tube of a feather, represents the like tissue in the hair of an animal; and the cellular medulla contained within the quill is the analogue of the medulla of a hair.

424. One striking difference exists, however, in hair, as compared with the feather of a Bird; it has been said that the hair-folli-

cle is so vascular that the bulb of the hair becomes red in a minute injection, no vessels, however, being visible. The follicle of a feather, on the contrary, is not only abundantly supplied with capillary blood-vessels, but more, the cellular medulla is intensely vascular. In other animals, as will be hereafter seen, when a hair is pulled out, it

FIG. 115.



Feather of a Rook injected.

FIG. 116.

Feather of a canary bird.

bleeds; proving a tendency to vascularity in this tissue, which, for all we yet know, may really exist. This will be best understood by consulting Fig. 115, which shows the feather of a *Rook*, the medulla of which is beautifully injected.

The arrangement of the capillaries will be seen to be peculiar, and characteristic; they are large, as compared with human capillaries, to enable them to transmit the larger-sized corpuscles of the blood. The corticle substance of the feather is marked *a*, the vascular medulla *b*.

FIG. 117.

Barb of a feather magnified.

425. But feathers differ from hair in another respect; the quill (*a*), terminating in a *shaft* (*b*), (Fig. 116), is covered on two sides by a feathered portion called *the vane* (*c*). The feathers of the vane are lamellated, or composed of a series of distinct plates called *barbs* (*c*); (Figs. 116, 117, *d*), these barbs are made up of still smaller barbs, called, therefore, *barbules* (*e*), (Fig. 117); and these are found to be provided with a series of very minute barbs or hooks, hence called *barbulinæ*—a still further diminutive (Fig. 117, *f*).

The latter are slightly hooked, to enable them to attach the barbules to

each other, so that the whole surface of the barbs, of which the vane consists, may form a solid, continuous, firm, resisting membranous expansion, by which a feather strikes the air, as an oar strikes the water.

Were it not for this beautiful provision, the air would pass through the feathers of the vane, and flight would be impossible.

426. The cuticular substance of human hair, is composed of a series of flatened cells or scales, derived from the epidermis thrown off or exfoliated, from the interior of the follicle. These cells or scales, are disposed in an imbricated (*imbrex*, a tile) form, or overlap each other, like the arrangement of shingles or tiles, on a house-top. This disposition of the scales can be proved by a very simple experiment; place a hair between the thumb and finger, and proceed to spin it round, by moving the finger and thumb contrary to each other; the hair will invariably pass through the *root end first*, which indicates not only the imbricated arrangement of the scales, but that they overlap *from* the root; this is shown in Fig. 118, the imbrications at the sides being exaggerated.

Fig. 118.

External surface, Human hair.

427. As these scales are attached one by one, as they become detached from the sides of the follicle, and the hair is always growing, it follows that no two of them can be deposited exactly in the same place—consequently they overlap; the lower part of a scale previously there, being covered by the upper part of a scale newly added.

428. The cortical fibres of the shaft of a hair are identical with the cells of the bulb; they become elongated as they are pushed upwards towards the mouth of the follicle, by the production of additional cells beneath, and are diminished in their diameter; consequently, the shaft of a hair is much less in diameter than the bulb.

Fig. 119.

Epidermic scales of Human hair.

429. The epidermic scales which cover the cortical substance, can be separated by the application of caustic soda, when they appear as represented in Fig. 119.

The dark spots, dots, or streaks, of the cortex are chiefly granular pigment; cavities filled with air or fluid, or nuclei.

430. Caustic Potash and Soda, soften and swell up the cortical

substance without destroying the spots, by which we see that they are nothing but pigment granules, deposited in the plates of the hair; they are frequently found in dark hairs, but vary very much in size and form. Other dark spots which, at first sight, appear to be pigment granules, prove to be, on closer examination, little cavities filled with air.

FIG. 120.

Plates from the cortical substance of the shaft of Human hair.

FIG. 121.

Scales from the root of the hair.

431. The root of the hair, especially the lower half of it, differs so far from the foregoing description, which applies to the shaft, that the scales, in this situation, appear as well formed elongated cells, each one possessing a nucleus. In Fig. 120, scales from the shaft, and in Fig. 121, from the lower half of the root, are shown; those from the shaft (Fig. 120) are flat and fusiform (spindled-shaped) in shape; those from the root (Fig. 121) are broader, and generally better formed, possessing a cylindrical, straight, or serpentine nucleus.

432. The medulla forms but a small portion of a hair; it is the central streak or axis, and extends from the bulb to the point, nearly. It is cylindrical in shape, and composed of a congeries of nucleated cells. If white hairs be boiled in caustic soda till they swell and coil up, simple pressure will generally demonstrate the cellular structure of the medullary cylinder, which is then sufficiently transparent for transmitted light. The medulla is remarkable for the great quantity of air which it contains; by its means the medullary cells are broken up into a series of distinct cylinders, of all lengths—some being much shorter than others. In examining a hair from bulb to point, it is curious to observe the many breaks which the medulla sustains, owing to the presence of air. A representation is given (Fig. 122) of a white hair from the head, which has been treated with caustic soda—

FIG. 122.

White Hair of the head.

magnified 250 diameters; *a*, nucleated cells of the medulla, without air; *b*, cortical substance, with distinct nuclei; *c*, cuticular covering, showing the imbrications.

Fig. 123.

Human eye-brow, showing air in the medulla.

433. To demonstrate the presence of air in the medullary cylinder, another illustration is necessary (Fig. 123); the most conspicuous object is the bulb (*a*), in which a dense aggregation of pigment cells is shown. From this point the medulla remains intact to *b*, where air is firstly found dividing the medulla; thence we see the frequent interruption of the medulla by the intervention of air, until it ceases near the point, *c*. The original specimen was a hair from the human eye-brow.

434. The whole of these facts, however, may be seen with advantage by consulting thin transverse sections of human hair (Fig. 124).

435. Here the cuticle (*a*), the cortical substance (*b*), and medulla (*c*), with its pigment cells, are well shown; the other figure (Fig. 125) was devoid of medullary pigment cells, at the point where the section was made.

436. The human hair is very elastic; it has been found by experiment that it will stretch to more than one-third its length without breaking. It readily imbibes water, and as readily gives it out again; consequently, it is sometimes *dry* and *brittle*, sometimes *moist* and *soft*, according as the skin, or the atmosphere, contains much or little moisture. Moreover, it becomes longer or shorter, according to the quantity of moisture it contains.

437. The chemical composition of hair has not yet been satisfac-

Fig. 124.

Transverse section, Human hair.

Fig. 125.

Transverse section, Human hair.

torily determined; some authors suppose it to consist of a combination of *proteine* and *sulphur*, to which others add a small quantity of a peculiar substance allied to gelatin. Hairs withstand putrefaction better and longer than any other part of the body; the hair of *mummies* is always found to be quite perfect.

438. As regards the imbricated structure of the cuticular covering, human hair closely approximates to *wool* (Fig. 126); and a bold attempt has been made in this country to prove that the hair of a *Negro* and *wool* are identical, and that, therefore, the Negro is an inferior animal, as compared with the white races of mankind.

FIG. 126.

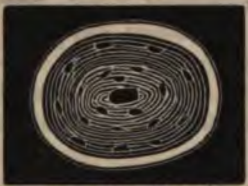
Wool.

This statement is supported in the work in question* by figures professing to be transverse sections of the hair of a white man, African, and full-blooded Indian, and the author makes them disagree remarkably. That of the white man, doubtless obtained from some accredited work on human physiology, is correct; the hair of the Indian is represented as round as a circle described by compasses; and that of the African as a long oval.

They differ as much in size as in shape; the European is shown as the smallest; next in size, and intermediate, is the Indian—the African hair being double the size of the latter.

439. In the following pages figures are given of the European, Indian, and Negro hair, all faithfully copied from existing preparations; these preparations have been measured by a Micrometer, and found to be of the same size, nearly. That the shape of hair (of the

FIG. 127.



Transverse section of hair, Negro.

FIG. 128.

Transverse section of hair, Negro.

head) is various in the same individual, will be seen from the two figures of hair from the white man, and two figures subjoined from the Negro (Figs. 127 and 128). Each presents a specimen with and with-

* "Trichologia Mammalium," by Peter A. Brown, LL. D., Philadelphia.

The author has published a description of his "cutting machine,"—the very worst form ever used! It is no larger round than an ordinary pencil case; the hair to be cut is imbedded in *cork*, and the instrument held in one hand, whilst a razor held in the other performs the cutting. The cortical substance renders hair a very tough, resisting tissue, and if only supported by cork, the latter yields to the pressure of the razor, and a *very oblique section* is the best result—hence the long oval that he has given of the Negro hair.

A cutting machine must be *fixed*, leaving both hands at liberty to use the razor, which requires great pressure to make a thin section, and the hairs should be constantly *moistened with warm water to soften them*, otherwise, with all possible care, the sections will be too thick to transmit light, or show their true structure.

out pigment in the medulla; that portion of the cortical substance which joins the cuticle is much darker in color in the Negro and Indian than in the white races, and this remark applies to the cortical substance generally. The hair from the head of a full-blooded Menomonee Indian (Fig. 129) agrees in all general characteristics with those already described.

440. Hairs of the beard are usually much larger and coarser

FIG. 129.

Transverse section of hair of Menomonee Indian.

FIG. 130.

Hair of the beard, white man; *a*, cuticular layer; *b*, cortical substance; *c*, medulla.

than those of the head; a figure of a transverse section of the hair of the beard of a white man is given at Fig. 130; in shape it is identical with a hair from the head of the same person (Fig. 123); the letters refer to the same tissues. All the foregoing specimens of hair were examined, and drawings simultaneously made, under a 1-4th object glass.

441. In the Negro, or mulatto even, the imbrications are much more distinct (because larger) than in the white races of mankind, owing to the fact that the epidermic scales, which enter into the composition of the cuticular covering, are themselves deeply colored with pigment, as already described in connection with the epidermis of the skin, and the darker the skin the darker and coarser the epidermic scales. Beyond this fact, there is nothing to distinguish the hair of a Negro, from that of any other specimen of the human family. As a rule, whether in a white man or a black, strong, coarse hair has a great disposition to curl.

LESSON XXVII.

HAIR, CONTINUED.

442. As a class of Microscopical objects, and as a valuable adjunct to Zoology, the structure of the hair of animals has excited

great attention within the last few years. The *Genera* of an animal, and frequently the *species*, can be accurately determined by the microscopical examination of a fragment of a hair.

In the higher mammalia, the hair appears to possess the same tissues as those described as belonging to the human hair, that is to say, the *cuticle*, the *cortex*, and the *medulla*.

443. Allusion has been made to the want of vascularity of the bulb of the human hair, and the interior of the follicle; if the *whisker* (vibrissa) of a cat be pulled out, it will generally bleed, proving vascularity in the follicle, if not in the bulb, of these particular hairs.

444. If a thin, transverse section be made of a *Tiger's* whisker (Fig. 131), the three tissues composing it are distinctly seen; the outer cuticular layer (*a*), the cortical substance (*b*), remarkable for the great amount of pigmentary cells included in it; and lastly, the

Fig. 131.

Transverse section, Tiger's Whisker.

Fig. 132.


Transverse section, Cat's Whisker.

medullary cylinder (*c*) in the centre, containing well-formed pigment cells, but devoid of pigment where this section was made.

A similar section of a Cat's whisker (Fig. 132) shows the same structure.

445. The Vibrissæ, as the whiskers of animals are called, are instruments of great importance to a vast number of them, but especially to the Feline races. All the cats, from the majestic lion down to our household pet, are not only *carnivorous* (feed on flesh), but they are *predaceous* (*præda*, prey),—seize living prey.

446. As soon as the eye discerns a victim, it is fixed with a deadly and unfaltering gaze; the creature creeps stealthily and noiselessly along upon the soft cushions of the feet, the eye having no part whatever in the direction taken; what then guides it? the Vibrissæ.

The Vibrissæ, measured from point to point, exceed the diameter of the widest part of the body; wherever they can pass without touching, the body therefore can follow. Their sensibility appears

to be exquisite, and in proportion as the point, or other part nearer the bulb be touched, the animal knows exactly whether it can pass or not.

447. For experiment sake, a cat has had her Vibrissæ cut, and then put into a box provided with a large round hole—larger than necessary for her body to pass through. But she has lost her gauge, and no temptation can induce her to attempt to come out of the box. Lions and tigers, following their prey in the jungle, are solely guided by the refined sensibility of these organs, which (as already observed) bleed when pulled out.

448. The true structure of hair can only be known by examining transverse sections of it, which require to be cut sufficiently thin, or they are useless.

449. Sections of the vibrissa of the Rat (Fig. 133), and of the Raccoon (Fig. 134), show the same tissues as those described in man; the air which separates the cells in the medullary canal in human

FIG. 133.

Transverse section of vibrissa, Rat.

FIG. 134.

Transverse section of vibrissa, Raccoon.

hair, is equally found exerting the like division in these hairs. Like the vibrissæ of the Tiger and the Cat, those of the Rat and Raccoon are remarkable for the general roundness of their figure. There can be no doubt that these organs are as important to the two last mentioned animals, as to the former; in the first, they tend to ensure the capture of living prey—in the last, they *facilitate escape*.

450. Hitherto, only one medullary canal has been described, as being excavated (as it were) out of the cortical substance; but in the *Pachydermatous* (thick skinned) animals, to which the *Elephant*, *Hog*, *Horse*, *Rhinoceros*, *&c.*, belong, there are several medullary canals apparent.

A thin transverse section of a hair from the proboscis of the Elephant (Fig. 135), is almost identical with a similar section of a Hog's bristle (Fig. 136), and in both, a plurality of medullæ appear

Fig. 135.

Transverse section of hair from the Elephant's proboscis.

Fig. 136.

Hog's bristle.

(*a*), in the cortical substance (*b*). Another section of a Hog's bristle (Fig. 137), made nearer to the lower portion, shows greater density in the outer part of the cortical substance, but the several medullary canals in its interior are fully apparent.

Fig. 137.

Hog's bristle.

They are, however, still better shown in the hair of the Elephant's tail, especially if the section be made near to the bulb; such an illustration (Fig. 138) is quite conclusive of the fact stated. The medullary canals (*a*, *a*), contain cells, most of them provided with pigment, while the cortical substance (*b*), is replete with pigment cells of the most perfect shape.

Fig. 138.

Transverse section of hair from the Elephant's tail.

451. Much difference, too, exists in the *form* of the hairs of the tail and proboscis; in the former they nearly resemble that of human hair; the latter, like the Hog's bristle, are nearly round.

Plurality of medullary canals may be seen in another tissue, which is to all appearance any thing but hair-like in its general characteristics.

If a thin transverse section be made of Baleen (*Whalebone*), it will be found to be composed of a dense aggregation of structures resembling so many distinct hairs, each having its medullary canal, surrounded by a cortical substance (Fig. 139).

If now a longitudinal section be made, the medullary canals will be very distinctly seen, divided periodically into a series of cellular cavities by septa (partitions) transverse in their direction (Fig. 140).

452. In structure, whalebone bears a wonderful resemblance to hair (Fig. 139), agreeing most with the pachyderm type, which ad-

FIG. 139.

Transverse section of Whalebone.

FIG. 140.

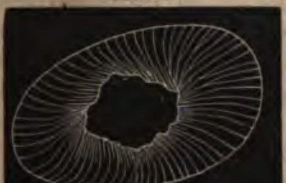
Longitudinal section of Whalebone.

mits a plurality of medullæ. The cortical substance is divided into a series of distinct bodies, each simulating a hair, and separate; is seen to be filled with medullary canals, which are, however, better seen in the longitudinal section (Fig. 140).

In the hair from the mane of a Horse, there is an exception to the rule of development of pachydermatous animals, as only one medullary canal appears (Fig. 141).

453. The male Turkey (*Meleagris galloparvo*) is provided with

FIG. 141.



Transverse section of hair, Horse's mane.

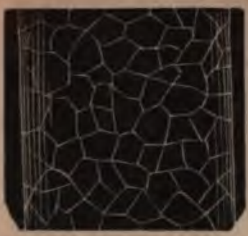
FIG. 142.

Transverse section of hair from Turkey's beard.

a tuft of very coarse hair, popularly known as the beard; in transverse section all the tissues are distinctly seen (Fig. 142). The

shape of it is very remarkable, and differs from all the other hairs in this respect. The *cortical* substance is uniformly dark—the

FIG. 143.



Hair of Stag, longitudinal.

FIG. 144.

Hair of Wapeti Deer, longitudinal.

FIG. 145.

Hair of Goat, longitudinal.

result of pigment existing in a diffused condition; the medullary canal partakes of the same irregularity of form which distinguishes the entire hair, its cells are well shaped, and pigment (when not interrupted by air) present.

FIG. 146.

Hair of O. paradoxus.

454. The hair of the *Ruminants* (*Ox*, *Sheep*, *Deer*, *&c.*) is peculiar; in them the cuticle cannot be found, because not present; the cortical substance supplies its place, and the medulla, transformed to large cells, filled only with air, constitutes the bulk of the structure.

In the Stag (*Cervus elephas*) the cells of the medulla (Fig. 143) are of great size; the dark cells are still full of air, which, in small portions, is always intensely black under the microscope; so too the hair of the Wapeti Deer (Fig. 144) is equally cellular, but of great beauty and smaller size.

455. In the hair of the *Goat* the two tissues (Fig. 145) are all that meet our gaze.

456. The belly of the Duck-billed Platypus (*Ornithorhyncus paradoxus*), is covered with hairs of a very curious form (Fig. 146). The bulb, at its extremity, is almost pointed; the shaft continues its course of nearly equal size for a considerable distance; at last it becomes attenuated, and gives evidence of terminating (as hairs usually do) in a very fine point. Instead of this, it suddenly and greatly enlarges, and this continues till it gradually diminishes and ends in a fine point.

At a short distance from the bulb, the narrow portion is filled with a series of well-formed cells (Fig. 147), like

the Ruminants; these, however, terminate just prior to the commencement of the enlarged portion. This latter at first contains diffused coloring matter (Fig. 148), which soon ceases, and the remainder of the hair is transparent.

457. The quills of the Porcupine (*Hystrix cristata*) are only modified hairs; all the required tissues being found in these structures, especially in the species quoted. The cuticular covering (Fig. 149, *a*), is seen as a delicate external ring; but by far the most remarkable structure is the cortical substance, which is transformed to horn, and gives amazing strength to the quill (*b*). Press it as hard as you will between the thumb and finger, no impression can be made on it, and to make a thin section it must be firstly softened by boiling. The pigment of the cortical substance is contained in a series of well-developed cells (*c*). The cortical layer consists of *two structures*—one (*c*) made up of cells, possessing pigment; the other (*b*) a layer of dense, non-nucleated horn.

FIG. 147.

Narrow part of the hair, O. paradoxus,

FIG. 148.

Structure of enlarged portion, O. paradoxus.

Fig. 149.

Transverse section Quill of Porcupine.

In the centre, and everywhere amid the cortical layer, the cells of the medulla (*d*) are seen.

458. The quills of the English hedgehog (*Erinaceous Europæus*) exhibit a like structure in a minor degree, but without cuticle.

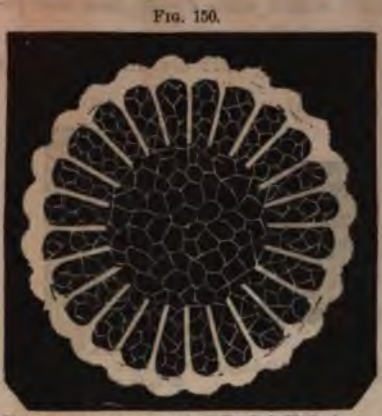
Two tissues are there, but the cortical substance descends into the interior of the medullary layer, without reaching the centre (Fig. 150).

The arrangement of the medullary cells is best seen in a longitudinal section (Fig. 151).

459. Lastly, the American porcupine (*Hystrix dorsata*) presents

a totally different aspect; here the cortical substance is restricted to a narrow ring, which forms the periphery of the circumference—all within it consists of medullary cells (Fig. 152).

FIG. 150.



Transverse section, quill of English Hedgehog.

It is easy to understand how the Indians can use these quills in such varied pattern; they have no support, and can be flattened with the greatest ease. In the two last illustrations the cuticle ceases to be present, and cannot therefore be shown.

460. Since we quitted the examination of human hair and wool, we have lost all trace of the external imbrications, and it might be inferred that these characteristics are confined to man, and the sheep; but this is by no means true, for, on the contrary, many animals there are in which this particular arrangement is shown in great perfection.

461. Thus, the hair of the seal (*Phoca vitulina*) presents them in

FIG. 151.

Longitudinal section, quill of English Hedgehog.

FIG. 152.

Transverse section, quill of American Porcupine.

a manner more nearly resembling a vegetable stem than any thing animal (Fig. 153).

462. The hair taken from the belly of the mouse (*Mus musculus*) is very interesting (Fig. 154). The imbrications are well shown, but its beauty consists in its cellular medulla; some cells are nearly white, others are intensely black; in some parts of its structure the

black and white cells alternate, occupying the whole diameter; in other portions the black is broken up into smaller rounded bodies, and mixed with the white. Neither is this all; the hair enlarges gradually from the bulb, then diminishes, and continues to do this four times before it ends in a point. Each enlargement, too, is always larger than that which preceded it, and the last the largest of all.

FIG. 153.

Hair of Seal.

FIG. 154.

Mouse Hair.

FIG. 155.

Bulb and shaft of the Hair, Phascogale.

A pretty little Marsupial animal (having a bag, or pouch, like the Opossum), from Australia, *Phascogale penicillata*, has hair somewhat resembling that of the Mouse, inasmuch as each hair consists of four enlargements (from the bulb), and corresponding diminutions. These hairs are of such great length, that it is out of the question to figure an entire one, especially as the principal has been demonstrated in the hair of Ornithorhyncus (Fig. 146).

But enlarged detached portions are illustrated: thus, a figure of the bulb, and commencement of the shaft (Fig. 155), is given. To

FIG. 156.

Succeeding portion, Phascogale.

FIG. 157.

Terminal enlarged portion, Phascogale.

FIG. 158.

Hair of Indian Bat.

this succeeds a well imbricated structure (Fig. 156), the interior of which displays medullary cells.

The latter structure now prevails throughout the remainder of

the hair, except in the attenuated portions, but to show the great disparity of size in the terminal enlargement, a figure of it (Fig. 157) is also given.

463. An exceedingly interesting and beautiful hair is obtained from a species of Bat, common in India, the scientific name of which is not known, although the hairs have been found in the cabinets of microscopists for fully twenty years. The imbrications are arranged as a whorl (Fig. 158) which surround the shaft. It is altogether unlike the hair of any other known species.

464. But it is reserved for still lower animals to show what extraordinary weapons hairs may become; in a Marine worm (*Aphrodita hispida*) the hairs are transformed into darts, and used as such (Fig. 159). The specimen from which the drawing was made, was dissected from the body of a naked (without a shell) Sea-slug—Aplysia—in whose integument a number of them were found It will

FIG. 159.

Hair of Aphrodita hispida.

FIG. 160.

Hair, larva of Dermestes lardarius.

FIG. 161.

Hair, larva of Dermestes, (more magnified).

be evident that, once in, there they must remain, as, from their structure, no power could extricate them, and consequently they were broken off, that the Sea-mouse (as these Annellides are called) might escape; but, is it possible to imagine a better shaped harpoon ?

465. A form of hair, from the larva of an insect (*Dermestes lardarius*) very common in larders in this country, is so curious in form, that it were unpardonable to omit it; moreover, it tends to show the great display of Almighty wisdom, even in the construction of a hair! Two figures of this hair are given, as seen by different magnifying power, and in different conditions; the first (Fig. 160) is perfectly spear-shaped, the imbrications being most distinct: this is magnified 300 diameters. In the second figure (161) the head of the spear is opened like an umbrella, a state in which these hairs are frequently found; it is now magnified 500 diameters.

466. The larva (upon whose body these hairs are alone found) does not exceed three-eighths of an inch in length, and appears to be a very quiet, passive animal. Whatever use it makes of these most remarkable hairs remains unknown, no one has even hazarded a conjecture in relation to them, notwithstanding there can be no reasonable doubt that they are defensive, as those of Aphrodita are offensive. Let the reader only imagine what the effect would be on another animal, advancing to molest the larva of Dermestes, and have all these hairs suddenly porrected (stretched forth), and the umbrella-like processes suddenly opened in its face!

The foregoing demonstrations have distinctly proved—firstly, the general character of imbrications as common to a majority of hairs; secondly, the important fact that hair, in man and most of the higher animals, consists of three distinct tissues; and, thirdly, that where a tissue is lost (cuticular layer), it designates, most usually, the smooth (non-imbricated) hairs.

LESSON XXVIII.

EPITHELIUM.

467. On the external surface of the body we found the skin protected by a layer of flattened horny scales, called Epidermis; this layer is continued over the outer surface of the lips, lining the whole interior of the mouth, covering the surface of the tongue, descending into and lining the *Œsophagus*, *Stomach*, and *Bowels*, but, in consequence of its altered form, under the new name of *Epithelium*.

468. This peculiar tissue is also found covering all other *Mucous*, *Serous* and *Synovial* membranes; it lines the heart, blood-vessels and

absorbents; the follicles of the mucous membrane, and all the glands; the *trachea* (windpipe) and all its ramifications, no less than the air-cells of the lungs.

469. Epithelial cells are various in figure, but resolve themselves into *two* chief forms—the tessellated or pavement epithelium, and the cylindrical, or cylinder epithelium.

Both these forms may be provided with vibratile cilia, and each has a tendency to run into the other.

470. The cells of the tessellated or pavement epithelium (Fig. 162) are flattened, and polygonal; they are attached to each other like the elements of a tessellated pavement, by the numerous angular surfaces each scale presents—hence the name bestowed on this particular form of epithelium. It occasionally happens, however, that they retain their original rounded or oval form, and in this case they are found separated by an interval of space from each other.

FIG. 162.

Pavement Epithelium; *a*, large cells; *b*, middle sized cells; *c*, cells with two nuclei.

471. All epithelial cells, without respect to form, are remarkable for the possession of a distinct nucleated spot; whence this nucleus is obtained is at this time a mystery; it is quite likely that they produce other epithelial cells, on the principle of cell development, and this is all that is known in relation to the subject.

472. The cylinder-epithelium is composed of elongated cells, cylindrical in their form; they are placed side by side, in a uniform series, the lower portion (frequently attenuated) constituting the base, and the upper, exposed portion, projecting into the free space of the tissue to which it is attached.

473. To see the well-formed cylindrical cell, a tissue should be selected with a flat surface; if it be convex, the lower ends of the epithelial cells are always of less diameter than the upper portion (attenuated), so that these epithelium scales much more resemble a series of truncated cones, than cylinders; this fact is well shown in the epithelium covering the villi of the intestines, of which more will be said in the proper place.

474. The *Cylinder* epithelium is found covering the entire surface of the alimentary canal, from the cardiac orifice of the stomach to its termination; it is also found in the ducts of the glands which

open into this canal,—the duct (*ductus choledochus*) which conveys the bile from the liver to the first of the small intestines (*Duodenum*), the salivary, and other glands.

475. Both the forms of epithelium already described, are frequently *ciliated;* the object of this arrangement appears to be to propel fluids over the particular surface upon which they are placed, and admirably they are adapted to this purpose! When these organs are moving in full activity, nothing can be seen but the incessant, rapid whirl of particles of extraneous matter contained in the water; when their activity begins to cease, the exact form of the motion then becomes visible. On such occasions it will be perceived that the *down stroke* is given with great energy and activity, the cilia recovering their position by a slower motion; this can be successfully imitated by striking the arm down very quickly, and lifting it back in slower time.

476. It has been already remarked in the Introduction, that the motion of vibratile cilia is alike independent of the will, and of vitality, as its action can be distinctly seen in epithelium removed from the body, long after death.

477. This phenomenon is not restricted to the human subject, or to the higher mammalia, but is much better seen, and for a greater length of time, in the lower forms of animal life. Thus: detached epithelial scales from the mucous membrane of the human nose, have been seen actively swimming through water by the agency of their vibratile organs, some hours after their removal; from the mucous membrane lining the air-tubes of man (*bronchi*), *for sixty hours after death*, and so vigorously, as to leave no doubt they would continue in motion for a much longer period of time; but the cilia of a *Tortoise* has been seen in active motion fifteen days after death, notwithstanding *the body* was putrid!

A view of ciliated cylinder-epithelium, of the truncated-cone form, is given (Fig. 163), in which the cilia (*b*) will be found occupying the upper enlarged portion; the nuclei (*a*) are clearly seen in the centre of each cell.

FIG. 163.

Ciliated epithelium.

478. If the tongue of a Frog be slightly scraped with a knife, and the product placed in a drop of water, and examined by the microscope, masses of ciliated epithelium of the pavement kind will be found (Fig. 164–1). These will be seen swimming through the water

at a great rate, especially when first procured, and they will continue so to do for a long time, or until the water evaporates.

479. The membrane covering the drum of the human ear (*membrana tympani*) is also the seat of ciliated epithelium (Fig. 164—2); likewise the human air-passages, as already remarked, a representation of which is given (Fig. 164–3). These three last forms have been drawn to scale so that their relative size may be ascertained, and in all of them nuclei are distinctly visible.

FIG. 164.

1. Ciliated epithelium from the Frog's mouth. 2. From the inner surface of human membrana tympani (drum of the ear). 3. From the human bronchial mucous membrane.

480. Like the cells of the Epidermis, the Epithelial cells are constantly being cast off, or exfoliated, and as constantly renewed. The time in which this is effected, however, is found to differ in tissues; thus, it is oftenest renewed in the mucous membranes devoted to the function of nutrition, where, in healthy digestion, the epithelium of the whole alimentary canal is said to be constantly thrown off after every meal; when this fails to be accomplished, disease is supposed to be the never-failing result.

481. On the contrary, as there is little action on Serous surfaces, the epithelium in such situations is much longer retained.

482. From the fact that two nuclei are not uncommonly found in one cell (Fig. 162, *c*), and that cells sometimes present a constriction, it is possible that they may be produced, like the vegetable cells, by spontaneous division.

SEROUS AND SYNOVIAL MEMBRANES.

483. The free surface of these membranes is found to be covered with Epithelium; underneath, is a layer of condensed *Areolar tissue*, which gives thickness, strength, and elasticity to the membrane. The yellow fibrous element forms a large portion of the composition of these membranes, and gives them elasticity in every direction.

484. Serous and Synovial membranes form closed sacs, which contain a fluid; that found in Serous membranes is nearly the same with the serum of the blood, and the fluid of Synovial capsules is the same, with an additional quantity of albumen.

485. Serous membranes are found in the abdominal cavity; thus, the membrane which lines the abdominal muscles, or the outer wall of the abdomen—*peritoneum*—from a Greek word, signifying *to extend around*, is a serous membrane.

486. Serous membranes invest the abdominal viscera, and pass from one viscus to another, until they have invested the whole of them, when they are reflected on the parieties (sides).

487. The Synovial membrane is a thin membranous layer, which covers the articular (joints) surface of the bones, from which it is reflected upon the surfaces of the ligaments which surround and enter into the composition of a joint. Like the serous membranes, these also are shut sacs; the peculiar fluid secreted by them is called *synovia.*

488. Certain sacs surrounding some of the joints are called *bursæ mucosæ* (mucous purses); these are shut sacs, allied in structure to synovial membranes, and secreting a synovial fluid.

LESSON XXIX.

THE ORGANS OF NUTRITION.

489. If, during the summer months, a drop of water containing animal or vegetable matter, or both, in a state of decomposition, be examined with a microscope, it will display a world of animated atoms!

These compose the individuals forming the class known as "*microscopical animalcula.*" The form and size, no less than other characteristics of the individuals of this class, is extremely various; some of them (*Monas crepusculus*) being so minute that a single drop of water would contain five hundred millions of them. Our present object, however, is to inquire into the particulars of their nutrition.

490. Prof. Ehrenberg long ago promulgated the idea that the majority of these creatures are endowed with a great but variable number of digestive sacs, each of which (according to him) is independent of the rest, but all of them communicating directly with the oral cavity (Fig. 165, *b*), as shown in the professor's figure of the *Monas termo*—supposed to be the most minute animal revealed to our vision even by the microscope.

Fig. 165.

Monas termo.

491. Increased knowledge of these creatures may probably demonstrate some mistake in connection with this description, which is at variance with all that we really know; the figures (of the same authority) of larger animals

of the same class, appear to be much more consistent; thus, the alimentary canal of *Vorticella citrina* (Fig. 166) is distinctly sacculated, and so, too, in *Stentor polymorphus* (Fig. 165); in all these figures the ciliated oral (mouth) aperture is marked *a*.

Fig. 166.

Alimentary canal, Vorticella citrina.

Fig. 167.

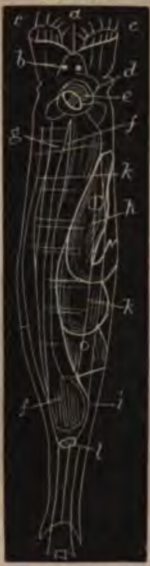
Alimentary canal, Stentor polymorphus.

In the Vorticella and Stentor (Figs. 166 and 167), the circular intestine is perfectly sacculated (*c*), or alternately dilated and contracted (*b*, *c*, *d*) throughout its entire course.

Two of the figures (166 and 167) are represented as dissected out of the body; this has been done by the mind's eye, for no earthly power is equal to such a task manually performed.

ROTIFERA.

Fig. 168.



Rotifer vulgaris.

492. The animals of this class have their vibratile cilia placed in *circular* or *semicircular* groups, and when in action they appear to revolve—hence their name. The so-called *wheel animalcule*, found in leaden gutters, and in infusions of hay, is a *Rotifer*, a view of which is given (Fig. 168). The mouth is seen at *a*; eye-spots at *b*; antenna (?) at *d*; jaws and teeth, *e*; alimentary canal, *f*, *g* (glandular, ?), mass enclosing it; *h*, longitudinal muscles; *i*, tubes, containing water, or blood; *k*, young animals; and *l*, cloaca.

The body of a Rotifer is more or less elongated; its posterior extremity is furnished with a pair of forcipated instruments, or claspers, which, when not required for use, can be retracted, and protected within a sheath.

493. The vibratile cilia are arranged in from two to five groups, placed on lobes, as shown in *Notommata clavulata* (Fig. 169, *a*).

This beautiful creature is as transparent as a

glass, and all the organs described can be seen in the microscope, if it remain quiet, with the utmost distinctness; it will be apparent that the alimentary canal, and all the organic structures, have made a great advance from the simple sacculated condition, and only one aperture of the Vorticella, and its allies.

494. These animals are remarkable for their tenacity of life. As early as the year 1701, Leeuwenhoek had been examining some specimens of *Rotifer vulgaris*, and left the water in which they were contained to evaporate. Two days afterward, having added some rain water, previously boiled, within half an hour he saw a hundred of the Rotifera revived, and moving about!

FIG. 169.

Notommata clavulata.
- *b*, *b*. Longitudinal muscles, which shorten the body.
- *c*, *c*. Transverse muscles, which diminish the breadth of the body.
- *d*, *d*. Ganglions (nerve knots) of the neck.
- *e*. Cervical ganglion.
- *f*. Pharynx, containing the jaws.
- *g*. Alimentary canal, terminating in
- *h*. a Cloacal outlet.
- *i*. Glands, either salivary or liver.
- *k*. Reproductive tubuli.
- *m*. Forcipated instruments for prehension.

A similar experiment was made, with the same results, keeping the animals dried up for a period of *five* months; and this has been repeated, and confirmed by many subsequent authorities, the time being extended to three years.

ENTOZOA.

495. The Entozoa are parasitic internal, or intestinal worms; of these, every known animal has its own peculiar species, and usually more than one; in man, no less than eighteen different species have been detected, occupying the various cavities and tissues of the body.

496. Excluded from the influence of light, they are almost uniformly white in color; deprived of air, they do not possess organs of respiration; they are, in short, little (if any thing) but sacs for the imbibition of nutriment.

FIG. 170.

The Acephalocyst.

497. The *Acephalocyst* (Fig. 170) consists of a globular or oval vescicle filled with fluid; sometimes suspended freely in the fluid of a cyst of the surrounding condensed cellular tissue, developing smaller acephalocysts, which are discharged from the outer or the inner surface of the parent cyst.

498. They vary from the size of a pea to that of a child's head; in the larger ones the wall of the cyst has a laminated texture. They are of a pearly whiteness, without fibrous structure, elastic, spurting out their fluid when punctured.

499. So far as known, there are two species of this animal; one the *Acephalocystis Endogena*, or the "pill-box Hydatid" of Hunter, most commonly found in man; and the *Acephalocystis Exogena*, found in the Ox, and other domestic animals. All these animals multiply by fissiparous division, precisely like the multiplication of the cells of plants, to which they appear to be most nearly allied. In the first named species, this process takes place from the internal surface of the parent cyst, and in the last, from the *external* surface—hence their specific names, respectively.

500. Another parasite, closely allied to the above, the *Cœnurus Cerebralis*, is found in the substance of the brain of Sheep, Calves, Pigs, Rabbits, and even Dogs, and produces a disease called (in England) the "gid," or "mad staggers."

501. In this disease, the animal affected by it appears to be "giddy," and staggers with the head down to the ground, or butting against extraneous substances in a state of apparent unconsciousness. A figure of this parasite is given (Fig. 171).

Fig. 171.

Cœnurus cerebralis.

502. The Cœnurus is one of the most simply organized animals, consisting of a large bag (*c*) always filled with water, at the end of a long neck (*b*), the summit of which is provided with suctorial mouths (*a*), adapted alike to adhesion to the tissues by which it may be surrounded, and for the procuration of nutriment. They are frequently found provided with many heads, which can be retracted within, or protruded without the common cyst.

503. This Hydatid form is by no means uncommon as a parasite in the animal kingdom and in man, and, wherever found, they invariably produce distressing, if not fatal disease. They have no sex, and appear to propagate most abundantly by the mere act of spontaneous division, such as is common to plants, and to the Acephalocysts.

Of course, there can be no cure for the Cœnurus, and the best that can be done is, to terminate the animal's suffering as soon as the "gid" makes its appearance. After death, pass a saw round the

skull, and remove the upper part, so as to expose the brain; an animal, like the figure given, will be invariably found.

Many Cystoid animals there are closely allied to the Cœnurus, and afflicting alike domestic animals, and man, but their effects are not immediately fatal.

504. The *Echinococcus hominis*, is a small animal cell, provided at its summit with a remarkable circlet, or coronet of teeth, by which it clings to the tissue, and four suctorial mouths for the imbibition of nutriment; they have been found in the liver and other organs of the human body (Fig. 172); *a*, head; *b*, suckers.

505. Another cellular animal (*Cysticercus cellulosa*) has been met with in the eye, brain, substance of the heart, and the voluntary muscles of the body (Fig. 173); in addition to the head, formed like the last, this animal possesses a long neck, which terminates in the nutrimental sac. The head, with its coronet of spines, *a*; the digestive sac, *b*.

FIG. 172.

Echinococcus hominis.

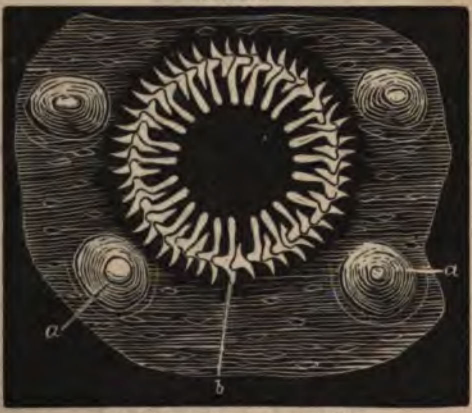
FIG. 173.

Cysticercus cellulosa.

A magnified view of the coronet of spines is given in Fig. 174; *b*, the spines, or teeth; *a*, the suctorial mouths.

506. These animals infest *Pigs* to an enormous extent, causing what is called *the measles*; and as the vitality of the ova is not destroyed in the process of cooking, those persons who eat fresh pork

FIG. 174.



Head of Cysticercus, magnified.

(not salted) need not be surprised to find themselves the victims of

507. *Tænia solium*, or *tape worm*, of which it is now well known

the Cysticercus is the young. The head of the latter animal is, in every respect, so identical with the former, that a figure of it is unnecessary.

FIG. 175.

D. hepaticum.

508. Two species of *Distoma* (*dis*, two; *stoma*, mouth) infest the human subject—D. hepaticum, found, as the specific name indicates, in the liver, and D. lanceolatum; of these animals, the former is also very abundantly found in the Pig. It is also sometimes found in large quantities infesting the liver of the Sheep, and in them it causes the *rot*. They are supposed to take up Planariæ with the water they drink, which, under altered circumstances of position, becomes a Distoma.

509. The nutrimental canal is very simple in both these animals. In D. hepaticum (Fig. 175), *a* represents the suctorial mouth, *b* the anterior sucker; the second is imperforate, and is simply an organ of adhesion. The alimentary canal is continued from the mouth for a short distance as a single tube, and then divides; the divisions run parallel with each other, and surround the ventral sucker, which is placed between *c*, *c*, and is also for the sole purpose of adhesion; the parallelism of the tubes is then continued to the caudal extremity. Each tube gives off several branches from the outer, and but few from the inner side; many of these branches are ramified, and all of them terminate in blind extremities near the margin of the body.

FIG. 176.

Distoma lanceolatum.

510. In *Distoma lanceolatum*, the suctorial pores are larger than in *D. hepaticum;* the anterior sucker is perforated by the mouth (Fig. 176, *a*), and the alimentary canal, commencing by a kind of pharynx, is continued as a very slender tube (*c*) for a short space, and bifurcates, each division being continued without ramification, on each side of the body to the tail, where it ends in a blind extremity (*d*). The ovaria are seen at *f*, and the oviducts at *g*. The second sucker is at *b*.

511. It is a very remarkable fact that nearly all the animals parasitic in man, are found in only one other animal—the Pig; and whether we obtain them directly from it, or whether it be another point of close affinity between the animal in question and humanity, has yet to be determined.

LESSON XXX.

ORGANS OF NUTRITION IN POLYPI.

512. We have now to consider the structure of an extremely interesting class of animals, moderately minute in size, and of wondrous beauty!

The Polypi (*poly*, many; *pes*, feet) are so called from their general resemblance to the many-armed *Cuttle-fishes*, and these obtained the name of "many feet" from the Greek naturalists. They are almost universal in their distribution; inhabiting the fresh water pools in great abundance, they form objects of surpassing interest to the naturalist.

513. But for endless variety of external form, associated with every shade of color, we must seek for these charming creatures in the Ocean.

The limits of this work will not permit an extended notice of these animals; and in the present connection we are in search of nutrimental organs, chiefly.

514. The fresh waters furnish three species of *Hydra*; *H. vulgaris*; *H. fusca*, and *H. viridis*, or green Hydra. Of these, the H. fusca is less common, and by far the most beautiful (Fig. 177). The tentacles, as the arms are called, are shorter than the body in H. vulgaris, but in this species they are of very great length, and when seen in a glass jar groping about, and searching for prey, present an object of incredible magnificence!

FIG. 177.

Hydra fusca.

515. The Hydræ are carnivorous; feeding upon the minute animals (especially Crustaceans) which are found abundantly in the same pools. The instant a tentacle touches an animal, although its body may be rotected by a shell, it

dies,—stung to death, paralyzed. It is then seized by the terminal portion of the tentacle, and conveyed to the mouth, while the other tentacles are incessantly in search of food, to supply the wants of an ever hungry stomach. This organ occupies the whole interior of the body—there is no intestine; the terminal portion of the body forms a narrow base, provided with a suctorial disc, for the purpose of attaching itself to aquatic vegetation.

516. The simplicity of structure of these creatures may be inferred from the fact, that they may be turned *inside out* without the slightest detriment; that which was the external surface instantly assumes the function of a true digestive stomach, while the stomach takes upon itself the office of a secreting organ, and produces young.

517. The mode of reproduction of the Hydræ is curious: a number of little bud-like processes make their appearance on the external surface, which soon resemble the parent in all their external characters; each possesses its mouth and tentacles, and although remaining attached to the body of the parent, proceeds to provide for its own wants. It is true that a canal of communication exists between the parent and the young bud, through which nutriment passes to help sustain it; but after a short time this canal closes up, and the young continue attached, or not, at their pleasure. A figure is given of a family group, such as those persons who have kept, and bred these animals, will immediately recognize (Fig. 178). The first figure (177) represents two perfect generations; the parent Polype (*a*), a young bud (*b*), and a more advanced one (*c*).

Fig. 178.

Hydra viridis.

This figure (178) shows three generations; the original parent (*a*), the first family (*b*, *b*), and the second family, produced from the first (*c*, *c*).

But apart from the process of budding (*gemmation*), there is another mode by which they can be produced in great quantity,

namely, by cutting them in pieces, when each portion will become a perfect animal.

518. We have referred to the Marine Polypi; do our readers chance to know that the *red coral* of Commerce, which forms such a pretty ornament for the necks of children, is composed of Carbonate of lime, and once formed the internal skeleton of a family of Polypes, by whom it was manufactured?

519. The Order of Polypes, to which *Corallium rubrum* (red coral) belongs, possess eight short, broad, leaflike tentacles around the mouth, and in this species they are white. The deeply red-colored skeleton is, as has been said, internal; it is covered by a red flesh, of paler color than the skeleton, and this is everywhere excavated into little cavities, for the reception of the individual Polypes. In this order the young continue to form a part of one common family, which may number several hundred individual members; they bear the same relation to each other, and the group with which they are connected, that the leaves bear to a tree.

520. The excess of nutriment due to the combined nutrition of so many members, goes to extend the common mass; to make new bone, cover it with new flesh, and to place in its cells a new family of Polypes. An illustration of this species is given (Fig. 179), in which the bone (*a*) is shown, covered with the flesh (*b*), and the polypes, with the tentacula displayed (*c*), emerging from the cells.

FIG. 179.

Red coral, polypes in situ.

FIG. 180.

Polype of Corallium rubrum.

521. To show the general structure, and especially the alimentary canal of this polype, a magnified figure is given (Fig. 180). The ex-

panded tentacles are seen at a; at the base of them (b) is the mouth; the stomach, provided with eight vertical partitions (d), occupies the centre of the animal. At the bottom of the stomach is an outlet (e) for the transmission of the nutrient matter to a canal, which communicates in like manner with the stomachs of all the polypes, by which means the nourishment is made available for the purposes of the commonwealth. Appended to the lower portion of the stomach are the ovigerous (egg-producing) tubuli (f).

LESSON XXXI.

ACALEPHA.

522. The surface of the Ocean, during the summer months, presents a vast assemblage of soft-bodied, gelatinous forms, of every size, from many feet diameter, down to an inconsiderable speck; all of them as transparent as glass, all luminous at night, and many of them sharply stinging the hand that touches them: from this latter property they obtain their name; the Greek word signifying *a nettle.*

523. The best account of these animals is that given by Peron and Leseueur, two French naturalists.

"The substance of a *Medusa* is wholly resolved by a kind of instantaneous fusion into a fluid analogous to sea water; and yet the most important functions of life are effected in bodies that seem to be nothing more than, as it were, coagulated water. The multiplication of these animals is prodigious; and we know nothing certain respecting their mode of generation.

"They may acquire dimensions of many feet diameter, and weigh occasionally from fifty to sixty pounds; and their system of nutrition escapes us. They execute the most rapid and continuous motions; and the details of their muscular system are unknown. Their secretions seem to be abundant; but we perceive nothing satisfactory as to their origin. They have a kind of very active respiration; its real seat is a mystery.

"They seem extremely feeble, but fishes of large size are daily their prey. One would imagine their stomachs incapable of action on these latter animals; in a few moments they are digested. A great number of these Medusæ are phosphorescent, and glare amidst the gloom of night like globes of fire; yet the nature, the principle, and the agents of this wonderful property remain to be dis-

covered. Some sting and inflame the hand that touches them; but the cause of this power is equally unknown."

524. Our ignorance of these animals is by no means so profound at the present day, albeit much yet remains to be discovered. John Hunter was the first to inject the stomach and communicating canals, and thus discovered the extraordinary route by which the nutriment reaches the digestive cavity, and also the channels by which the digested aliment is distributed for the support of the general system.

Fig. 181.

Rhizostoma Cuvieri.

The animal on which the experiment was made, belonged to the Genus *Rhizostoma* (*rhizoma*, a root; *stoma*, a mouth), and a figure of it is appended (Fig. 181).

525. Every part of the body of this *Rhizostoma Cuvieri* is of the utmost transparency, so that the internal organs may be distinctly seen through the external parietes of the mantle.

The gastric cavity, or stomach (*d*), is in the centre, surrounded by four ovarial sacs (*e*, *e*, *e*). A number of wide vessels extend from the circumference of this quadrangular stomach to the purple-colored, highly vascular, lobed and respiratory margin of the disc (Figs. 181 and 182, *h*, *h*).

Fig. 182.

Section of Rhizostoma.

The peduncle hangs suspended from the centre of the disc, and is divided into eight branches (*c*, *c*), which terminate in simple lobed dilatations (*a*, *a*), having their surface marked with numerous depressions, which are the orifices of internal canals (*a*, *b*, *c*), leading upwards to the stomach (*d*). In the middle and upper parts of these

eight branches there are fimbriated (fringed) membranous extensions (181, *f*, 182, *f*, *k*), the numerous vessels of which also anastomose with the principal ascending trunk of each peduncle. On making a vertical section of this Rhizostoma, thus injected, through the centre of the disc (182), the internal canals (*b*, *c*) are seen, commencing from the orifices of the branches (*a*), receiving all the lateral absorbent canals (*f*, *k*) in their course, and uniting above to form one large œsophageal passage (*m*) before entering the central gastric cavity (*d*). The peduncles divide and subdivide like the roots of a plant; the œsophageal canals follow these ramifications, and ultimately terminate in numerous pores (*f*), upon the margins of the branches and clavate (clubbed) ends of the ramified peduncles. These pores are the commencement of the nutritive system; they are analogous to the numerous polype-mouths of the compound coral animal.

Minute animalcules, or the juices of a decomposing larger animal, are absorbed by these pores, and conveyed by the successively uniting œsophageal canal to the stomach.

The nutrient fluid passes by vessels which radiate from that cavity, to a beautiful network (182, *h*, *h*) of large capillaries, which spread upon the under surface of the margin of the disc. Thin membranous partitions (182, *l*, *l*) separate the cavity of the stomach (*d*) from the four ovarial sacs, which open externally by distinct apertures (*i*, *i*).

526. In some of the higher Medusæ, as in *Cetonia aurita* (having lobes like the ear), the mouth is single, and opens directly from the centre of the lower surface of the mantle, into a capacious stomach, from which numerous vessels radiate to a circular canal surrounding the margin of the disc. The mouth of Cetonia is of quadrangular form, supported by four curved cartilaginous plates, from which are suspended four elongated, tapering lips, or tentacula (Figs. 183 and 184, *a*, *a*). On inverting the disc (184) the short, four-sided œsophagus is seen in the centre, leading to a capacious gastric cavity, partially divided into four sacs (183 and 184, *c*, *c*), and from each of these sacs numerous alimentary canals (183 and 184, *b*, *b*) radiate towards the margin of the mantle, ramifying with great regularity, but presenting few anastomoses compared with those of the Rhizostomes.

Around the lower part of the stomach the four ovarial sacs (184, *c*) are placed, containing the colored ovaries, and opening externally, each by a distinct aperture. From around the margin of the stomach, sixteen canals come off, alternately simple and ramified, which end in

the circular vessel (184, *d*) passing round the margin, and by placing the living Medusa in sea water tinged with indigo, the stomach (183, *c*), the radiating vessels (184, *b*, *b*), and the circular marginal canal (184, *d*), are soon found to be filled with the blue coloring matter,

Fig. 183.

Cetonia aurita.

Fig. 184.

Cetonia aurita.

while the rest of the animal remains colorless. The free margin of the mantle is fringed with a row of minute tentacula, which appear to be highly sensitive, and in constant motion; the organs of vision (according to Ehrenberg) are placed in the slight depressions around the free edge of the disc (*e*, 183; *f*, 184).

LESSON XXXII.

ORGANS OF NUTRITION IN THE ECHINODERMA.

527. The bodies of Star-fishes, Echini, &c., are more or less covered with spines (Fig. 185), and hence the name of the class, which is formed from *echinus*, a spine and *derma*, skin; frequently they are called the *prickly-skinned* animals.

Fig. 185.

Echinus.

528. The digestive apparatus in the Star-fishes, and its immediate allies (*Euryale*, *Ophiura*, or brittle stars, *Asterias*,

&c.), is very simple; like the Hydra, it consists of a single sac, with but one aperture.

In others (*Comatula, Encrinus*), the digestive canal is more lengthened, and curves upon itself, and has an outlet distinct from the mouth.

In the *Echinida* (*Sea-urchins*) and *Holothuridæ* (*Sea-cucumbers*) there is a long, narrow, convoluted intestine, passing through the body, with very slight gastric enlargement.

In the higher forms of Star-fishes (Holothuridæ) the folds of the long intestine are connected by means of a highly vascular mesentery, which, whether injected artificially or otherwise, presents an object of surpassing beauty.

529. The mouth of the *Asterias* (Fig. 186) is placed in the centre of the inferior surface of the body, surrounded by long tubular tentacula, and protected by fasciculi of calcareous spines.

FIG. 186.

Nutrimental organs, Asterius rubens.

By means of a very short œsophagus, it leads directly to a wide and very dilatable stomach (*a*), provided with a distinct internal mucous lining, and an external muscular coat.

It occupies the whole central part of the body, from which the marginal divisions originate. From the stomach two long, tapering, ramified cœca, which commence by a single trunk, are given off opposite the commencement of each ray, and are distributed through it in a central line, so that collectively there are ten pairs of the cœcal appendages (*b*, *b*).

530. Each of these cœca is attached to the integument along the upper part of each ray, by a delicate vascular membrane. In addition to these appendages, the stomach is also provided with small, short cœca (blind sacs) at its upper part within the disc, and at its sides, between the great cœcal trunks of the rays.

531. The Echinida (Fig. 187) present a more elevated form of the nutrimental organs; the mouth is furnished with five large and

powerful teeth, called the "Lantern of Aristotle," for the comminution of the food (Fig. 188). It is a singular fact that, in this Class, the number *five*, or its multiples, constantly meet us: *five* rays, *five* teeth; *ten* cœcal appendages, and so on. In the Class Acalepha,

FIG. 187.

Nutrimental organs, Echinus.

FIG. 188.

The Lantern of Aristotle.
a, The Teeth.
b, The Alveolar processes.
c, Hooks for the attachment of muscles.

four and its multiples are as constantly found; the tentacles are *four* in number or *eight*; and this principle is constant in these two classes.

532. The teeth (Fig. 188, *a*) are three-sided prisms, dense at the lower, pointed extremity, softer at the base, with their inner edge sharp and fit for cutting; they are each implanted in a larger triangular pyramid (*b*), two sides of which are in close apposition with opposite sides of the adjoining pyramids, and are transversely grooved, like a file.

A further view of two of these teeth, in apposition by the alveolar processes, is given (Fig. 189). The upper, soft portion of the teeth is shown at *a*; the terminal, hardened part at *b*; the alveolus at *c*. The secretion of some simple salivary follicles assist in completing the mastication of the food. These teeth are put in motion by a series of well-developed muscles, said (by Valentin) to consist of the striped fibre.

FIG. 189.

Two of the Teeth of Echinus, natural size.

533. In the cavity of the lantern is the pharynx, which is divided by five longitudinal folds; the salivary cœca are placed in its immediate neighborhood. A slender œsophagus

(*c*) leads to the gastric portion of the intestine (*d*); and that canal twice winds round the circuit of the abdominal cavity before its final termination. The intestine is generally found loaded with fine sand; its surface, and that of the vascular mesentery, is covered with a rich network of capillary blood-vessels.

534. Near the œsophagus is a fusiform, dilated, contractile vesicle; this is the heart, and by tying a small pipe in it, and passing injection through it, the whole vascular system will be beautifully displayed. A trunk proceeds from the heart, which forms a circle round the œsophagus, at the base of the lantern; a second trunk proceeds from the opposite end of the heart, and forms a similar circle round the vent; an artery and a vein also run along the concave margin of the intestine; the blood is of a yellowish color, and exhibits a distinct nucleus.

HOLOTHURIA.

535. These animals have been likened to a lengthened Echinus, deprived of its calcareous plates, and with its axis extended in a longitudinal direction. The skin is usually soft and leathery; in a few genera, strengthened by calcareous spines. Five avenues of suckers, terminating the long retractile tubular feet, divide the body into as many longitudinal segments, which, in the majority, are of equal, or nearly equal dimensions. In some species the suckers are developed only on one side; in other species the body is entirely covered with them; the suckers are similar in every respect to those of Echini and Star-fishes.

FIG. 190.

Cucumaria frondosa.

536. The mouth is surrounded by plumose tentacula, usually of great beauty; when complete, the number is always *five*, or its multiple (Fig. 190). The tentacula can be withdrawn into the mouth by means of its proper muscles, and in captivity they frequently tantalize the eager naturalist by retaining them in the interior of the body for days together; nay, they often die with them in this position.

537. They are provided with a circle of teeth, analogous to those of the Echini.

538. The œsophagus passes through this circle, and opens into a more or less muscular stomach, from which an intestine, often very complicated, proceeds to the posterior portion of the body, where it dilates into a cloaca, from which two long ramified tubes (the respiratory organs) originate. These facts are demonstrated in the annexed figure of *Holothuria elegans* (Fig. 191).

The mouth is shown at *a*; the tentacles, in this instance retract-

FIG. 191.

Holothuria elegans.

ed, at *b*; the stomach is seen at *d*; a biliary follicle (or, what is more likely, the ampulla Poliana, a bottle), which would seem to be peculiar to this species at *c*; the very long, convoluted intestine is continued from the stomach, and designated by the same letter *d*, *d*, *d*,

8

until it terminates in the cloaca, *f*; it is connected to the body in several places by a mesentery of great vascularity (*e*, *e*), which also connects one fold of the intestine to another.

539. The branchiæ (gills, *h*), which arise from the cloaca, give off a great number of ramified branches from the central stem. They are always filled with sea water, from which the gills possess the power of eliminating the oxygen; the vesicles, or cells of the gills, are described at *m*. The blood-vessels which pass from the mesentery to the gills, conveying the blood to be aerated, are shown at *n*; and the external opening of the cloaca at *g*.

Seen in a recently killed specimen, these gills form a very interesting object; they then seem to exhibit a constant vermiform motion, which continues long after the apparent death of the animal.

540. One fact in connection with Holothuria is too remarkable to omit. Those persons who handle a living specimen for the first time, will be surprised to find that, without the slightest provocation, the integument suddenly bursts, and the whole contents of the body are violently thrown out; neither is this all, for, if the emptied skin be thrown into a vessel of sea water (which should be renewed daily), the alimentary canal, and all the lost organs—including the teeth and the tentacles—will be reproduced.

541. This act appears to be due to the excessive irritability of these animals, which, when once excited, appears to be beyond its power to control. The muscular system is of enormous power, especially in the transverse direction of the body.

542. To enable the creature to shorten its length, and to retract the head, strong tendinous chords are attached to the muscular coat; of these, five are devoted to the head alone.

543. The *Cucumaria frondosa* is the reputed largest Holothuria known; Fig. 190 is copied from a specimen, now in the Hunterian Collection, England, which measures twelve inches in the dead state; beside it, in the Museum, is a preparation of another individual of the same species, which, in life (sometimes) measured three feet—it did so at the moment it was killed, and at the instant—contracted to four inches, all that it measures now.

544. The sexes in these animals are separate; the important organs of the female—the tubuli containing an immense quantity of ova—are seen at *k*. These, filled to repletion with their valuable contents, form a very interesting object for the microscope, while the rich orange color of the ova contributes greatly to the attractiveness of such a preparation as that figured.

545. From the amazing number of ova deposited by the various species of Holothuria during only one season, they ought to be the most abundant of all animals, instead of being moderately rare; the probability is that their eggs are greedily eaten by small fishes, Medusæ, some Zoophytes, and, in fine, by the host of small Carnivora incident to the ocean.

A preparation of the Ovarium of Cucumaria frondosa, dissected out of the body, is shown in Fig. 192. The tubuli are suspended by the oviduct (*a*), the tubes being quite full of ova, of a rich orange color. The organs of reproduction are placed in the head, between the tentacula; the external orifice of the oviduct is a small, dark-colored papilla, which (unless carefully sought for) might easily elude detection. An enlarged view of these ovarian tubuli, showing their contents, is given in Fig. 193.

FIG. 192.

Ovarium, Cucumaria frondosa.

FIG. 193.

Enlarged ovarian tubuli, C. frondosa.

546. One of the most elegant preparations the animal kingdom can furnish, is the respiratory organs of Holothuria.

Those of Cucumaria frondosa are reduced from eleven inches in height, and shown in Fig. 194. The cloaca (*a*) is entirely covered with strong, flat muscles, which were attached to the muscular coat of the integument. Great muscular power is necessary to this organ, whose constant function it is to draw water from the ocean, pump it up to the minutest sac, or modified air cell (*d*), and discharge it when unfitted for further use. Beside the Cloacal outlet, there must be a series of minute apertures, which have hitherto defied discovery in connecting with this apparatus, for, if a specimen (previously accustomed to handling, by being tickled daily, in sea water) be care-

fully lifted out of the vessel containing it, on the palms of both hands, five beautiful, minute jets of water, crossing each other in various directions, will frequently be seen; so great is the quantity of water contained in the respiratory apparatus, and so small the apertures, that the streams will continue steadily to flow for *half an hour*.

547. The intestine, which, as before described, also terminates in

FIG. 194.

Respiratory organs, Cucumaria frondosa.

the cloaca, is shown at *b*; the respiratory tubes, with their ramified branches, at *c*. These organs, like the alimentary canal, are confined to a given situation in the interior of the body: the latter, by means of the mesentery, the former, by a series of round, white, tendinous chords (*e*, *e*).

Authors who have only seen such a preparation, and know nothing of its connections by manual examination, have greatly mistaken the character of these tendons; thus Grant (and others) describes them

"as follicles," and add that "they pour their secretion into the respiratory organs." *

SIPUNCULUS.

548. The rough Syrinx, Tube-worm, or Sipunculus, according to modern classification, is a very curious animal, and as much (apparently) unlike a Star-fish as can be imagined. It is, however, closely allied to Holothuria.

549. The body is cylindrical, and covered with a strong coriaceous (leathery) integument, generally rugous (wrinkled), except at the posterior extremity, which is longitudinally grooved to its termination. A specimen, about two inches long, is represented in Fig. 195. On opening a similar specimen, a very curious condition of the nutrimental apparatus presented itself; the gastric cavity (Fig. 196, *a*), is clearly distinguishable; this terminates in an intestine (*b*) apparently filled with fine sand, which is of considerable length. It descends in a tortuous course to the posterior portion of the body; it then winds upon itself in a series of close folds, and terminates by a small tube (*c*) at the vent, which is situate near the base of the proboscis (the latter not exceeding one-tenth of the body in length), close to the anterior extremity. The longitudinal muscles are beautifully displayed, and several strong tendons, some oblique in their position, are equally well shown. Two long, narrow, sacculated bodies (*d*, *d*) are seen, but whether they are glandular, or Ampullæ (like a bottle; the heart of Holothuria is

FIG. 195.

Sipunculus.

FIG. 196.

Nutrimental organs, Sipunculus.

* In the year 1841, the author had thirteen living specimens of C. frondosa, in his possession in Edinburgh. After a variety of interesting experiments with the living animals, he displayed their anatomy in a series of preparations now in the Hunterian Museum. Drawings of them, of natural size, he possesses.

so called—usually with the addition of the name of its discoverer, Poli—thus: ampulla Poliana), or belong to the reproductive function, is difficult to say—most likely the latter. Out of *four* animals of this species dissected, and made into preparations (which exist), no trace of tentacula was found in either of them.

Fig. 197.

Muscular system, Sipunculus.

The muscular system in these animals, like that of Holothuria, is powerfully developed. It is arranged (as already shown) in longitudinal parallel fibres, whilst the head can be retracted by a very strong tendon, attached to it, and inserted by a broad expanded base, below the lower third of the animal's body.

A view of the muscular system, dissected out of the integument, is given in Fig. 197. The muscles are described at *a*, and the tendon, above referred to, at *b*.

LESSON XXXIII.

ORGANS OF NUTRITION IN THE ANNELLATA.

550. The Latin name which distinguishes this class is derived from *anellus*, a little ring, the bodies of all the individuals belonging to it being composed of a series of little rings, or segments.

551. A peculiarity of this class is, that they all possess colored blood, generally red, although in some species it is yellowish; from this circumstance they are very usually called "the red-blooded worms." Many of these animals are Terrestrial (belonging to the earth), as the common Earth-worm (*Lumbricus terrestris*), or Angle worm, but by far the greater number are inhabitants of the ocean.

552. The most attractive portion of the structure of a majority of the marine worms, is the respiratory tuft, which is placed (in some species) at the summit of the head. A very common marine worm is the *Serpula contortuplicata*, a figure of which is given (Fig. 198).

553. When all is quiet, and the creatures are luxuriating in

their native element, they thrust their respiratory organs (*c*) far above the head, the vibratile cilia being, at the same time, in rapid motion. But if any thing chance to disturb them, the respiratory tuft is instantly withdrawn into the tube (*a*) in which the body is contained, and the conical plug (*b*), formed like the shell, of carbonate of lime, but covered with flesh, is drawn tightly down, and effectually closes the entrance to the tube. At the top of the conical plug a pair of forcipated instruments are placed; it is their function to collect sand, and "puddle" it down, so that it fill entirely the concave summit with a compact layer of sand; by this expedient they frequently escape molestation by even pretty good naturalists, who affirm that "the animal is dead, and the shell filled with sand."

FIG. 198.

Serpula contortuplicata.

FIG. 199.

Alimentary canal, Aphrodita aculeata.

554. Much uniformity of plan prevails in the structure of the nutrimental organs in this class, consisting for the most part of a tube, generally possessing enlargement of the gastric cavity (stomach), which passes straight through the body.

555. In some of the higher worms, as in the Sea-mouse (*Aphrodita aculeata*), the strong, muscular, gizzard-like stomach is supplied, at its terminal portion, with the secretion of a great number of long follicular glands.

556. In the annexed figure of it (Fig. 199) the mouth is shown at *a*, a

dense fleshy proboscis at *b*, the central portion of the digestive tube, which represents the stomach, at *c*; lateral, cœcal appendages at *d*, and the vent at *e*.

557. The Leech presents an interesting form of the nutrimental organs; the mouth is triangular, and armed with three crescentic jaws (*a*, *a*, Fig. 200), presenting their sharp convex margin toward the oral cavity, which margin is beset with sixty small teeth (Fig. 201).

It is by the action of these little saws upon the tense integument seized by the labial sucker that the triradiate bite of the leech is made; the muscles of the jaws are marked *b*, *b* (Fig. 200).

558. The œsophagus is short, and terminates in a

Fig. 202.

Nutrimental organs, Leech.

Fig. 200.

Mouth of Leech.

Fig. 201.

Jaw of Leech.

singularly complicated stomach, divided by deep constrictions into eleven compartments, at the sides of which are cœcal pouches, progressively though slightly increasing in length to the tenth, and disproportionately elongated in the eleventh compartment (Fig. 202).

559. Army Surgeons, who have required more leeches, after an engagement, than they possessed, have availed themselves of the knowledge of this peculiarity in the structure of the creature's alimentary canal, to make one leech do the work of several, by simply cutting off the lower part of the body, when the blood pours out in a rush, emptying the canal immediately.

Thereafter, the leech continues to suck blood, as long as he is permitted to do so; he always feels empty—so his appetite continues voracious.

560. It is a common practice (in Europe), after a leech has left a patient, to throw salt upon it, to produce vomiting, which it invariably does, but it kills the leech.

561. The best plan is, to hold it firmly at the posterior portion of the body with one hand, and draw it steadily through two fingers

of the other hand, using some pressure at the same time. By this mode of "stripping" the leech, the stomach, and the lateral pouches will be entirely emptied, and the animal soon becomes ready to renew his labors.

562. Although ever ready to relieve suffering humanity of inflamed, or otherwise diseased blood, this does not constitute the natural food of the leech; it is well known in the sick room that, while the majority of them die from the effects of their first sanguinary meal, those of them that recover remain in a weakly condition for some weeks afterwards; and it rarely happens that one leech will do duty a second time.

FIG. 203.

Arenicola piscatorium.

563. In the sand-worm (*Arenicola piscatorium*—the fisherman's worm) the blood is of a most brilliant red, and the highly vascular, respiratory tufts, form charming objects (*l*, *l*, Fig. 203), with or without the microscope.

The mouth is at *a*; the gastro-intestinal canal commences at the termination of the œsophagus (*b*) by a sudden dilatation, into which two cœcal glandular pouches (*c*) pour their secretion; the rest of the canal is simple in its outward form, but its walls are thickened by a stratum of minute secerning cells (*g'*), which prepare a greenish yellow fluid.

The circulation of the blood in this worm is very interesting; there is on each side of the œsophagus, at its lower part, a contractile sac (*f*), which sends off a large and short vessel downward, toward the middle ventral line, where, meeting with its fellow trunk, a ventral vessel (*e*) is formed. This vessel (*e*) furnishes a pair of transverse branches to each ring of the body, which, at the seventh segment, penetrate the branchial tufts (*l*, *l*) attached to the sides of that and succeeding middle segments of the body. The pulsations of the two œsophageal ventricles (*f*) propel the blood into the ventral vessel (*e*), through the vessels (*m*, *m*) to the gills, where it receives a new

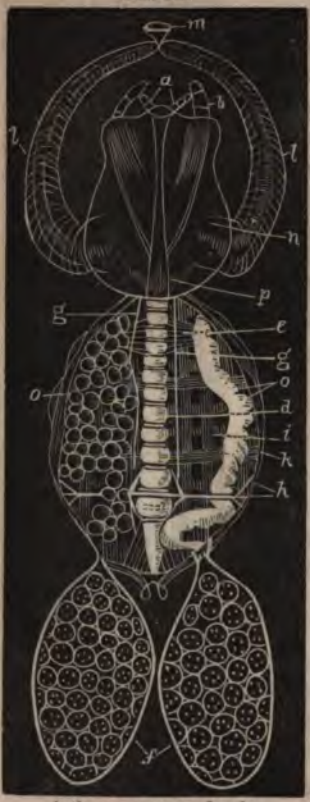
impulse by the contractions of these organs, and, after having been oxygenized, it is returned, partly by vessels of the skin, but chiefly by a direct and continuous lateral vessel (*k*, *k*), to the dorsal artery (*g*).

This artery extends from one end of the body to the other. At its middle part it receives many transverse branches from the digestive tube, and through them joins the inferior intestinal vein (*h*). The vascular network thus formed around the intestine gives origin to two veins at the sides (*i*), which terminate in the dorsal vessel, immediately behind the ventricles (*f*, *d*).

LESSON XXXIV.

ORGANS OF NUTRITION IN THE EPIZOA.

FIG. 204.



Aetheres percarum, female.

564. The Epizoa (*epi*, upon; *zoon*, an animal) form a most extraordinary class of animals. They are external parasites, usually on the bodies of Fishes, where they attach themselves to the skin, the eyes, and the gills. Their number is prodigious, probably exceeding that of the fishes they infest.

Limited space will not allow of more than one illustration of this class—the *Actheres percarum*—found attached to the eye of the Perch.

565. The mode by which the Lernæa (as these animals were called by Linnæus) adhere to their prey, is peculiar, and characteristic of the class. A pair of hollow, tubular feet, adhering by their terminal extremities (Fig. 204, *l*, *l*), gives origin to a cup-shaped sucker (*m*); this is the instrument of adhesion.

566. The mouth consists of upper (*b*) and under jaws, the latter provided with feelers; besides these, a pair of jointed antennæ, each terminated by three small bristles (*a*). The alimentary canal is, as in all

these animals, straight, and terminates by a vent, at the extremity opposite to the head. The intestine is fusiform, and divided by a series of slight constrictions into sacculi (minute sacs, *d*).

It is maintained in its position by a transverse muscle (*h*); the walls of the abdomen are distinctively provided with longitudinal (*i*) and transverse (*k*) fasciculi of muscular fibres.

567. The nervous system consists of a single cephalic ganglion, placed on the ventral surface, from which are continued two principal chords (*g*, *g*) extending along the under surface of the body. The heart may be seen in the middle line of the cephalo-thorax (head, chest), propelling the blood forwards. Two canals pass from it into the hollow feet; the rest of the blood is distributed to the head, and along each side of the commencement of the alimentary canal to the under part of the body, where it passes backwards in the vessel which accompanies the intestine.

568. The ovaria (*o*, *o*) at first appear as long, blind tubes, sacculated along the outer side. As the ova become developed, the ovarium takes on the form of a bunch of grapes, and occupies the whole cavity of the abdomen external to the intestine; each ovarium terminates by a triangular, and somewhat prominent orifice, to which the *external ovisac* (*f*) is appended. This latter structure agrees with the form of external ovisac in the lower crustacea, into which the ova pass from the abdominal cavity (having attained a certain degree of maturity) through the oviduct *e*, for their full development, previous to the fertilizing influence of the male.

FIG. 205.

Actheres percarum (Male).

569. The disparity of size in the sexes is considerable, as appears by the annexed figure of the Male Actheres (Fig. 205).

LESSON XXXV.

ORGANS OF NUTRITION IN CIRRIPEDIA.

570. Like the *Epizoa*, many of these animals are parasitic, but unlike the latter, these have only a residence on the bodies of animals, obtaining their food from other sources: thus the *Tubicinella* is parasitic in the skin of the Whale, but it does not obtain its sustenance, or any portion thereof, from the animal whose skin it inhabits.

571. The Cirripeds (meaning *curled feet*) are divided into two orders: those having a peduncle as an organ of attachment, are the *Lepads*, and those which are *sessile* (sitting close upon the body), are the *Balanoids*. The first, are commonly called *Barnacles;* the second, *Acorn-shells.*

572. The visceral mass in this class is usually protected by a calcareous shell composed of several pieces; but in *Otion cornuta*, the viscera is protected by the development of a horny sheath.

573. In the common Barnacle (*Lepas anatifera*), found so abundantly adhering to ships' bottoms, the calcareous matter extends from five centres, so as to afford protection to the whole body: the cephalic pair of valves is the largest. All the valves are strongly marked with lines of growth, formed by successive additions to their margins.

574. The sessile Cirripeds (*Acorn-shells*) are defended by a multivalve shell; the base of which is generally formed by a calcareous plate, and the walls are apparently divided into twelve conical compartments, six of which rise from the margin of the base and terminate in a point at the free margin of the shell; whilst the other six, in the form of inverted cones, occupy the interspaces of the preceding series.

575. One illustration of the structure of a Lepad will suffice: animalcules, or other proper food, are brought to the mouth (*a*, Fig. 206) by the cirrigerous feet (*b*), and seized by the lateral jaws; they are then conveyed by a short œsophagus to a dilated stomach (*c*), which receives the ducts of two salivary glands (*k*). Groups of hepatic cœca are developed from the walls of the stomach. The intestine (*d*) is bent upon the stomach, and tapers with a slightly sinuous course to terminate at (*e*), the base of the caudal appendage (*f*). In these pedunculated Cirripeds, slender conical branchiæ (*g*) are attached to the base of the maxillary foot, and to that of some of the cirrigerous feet.

FIG. 206.

Lepas vitrea.

In the pedunculated Cirripeds, a large granular, glandular mass covers the viscera immediately beneath the muscular tunic of the body; its numerous ducts successively unite into three or four principal trunks, which terminate in a lateral receptacle (*h*) at the side of the intestine. In Lepas, a duct is continued from this receptacle, which passes through the canal of the extensile tail (*i*).

LESSON XXXVI.

ORGANS OF NUTRITION IN THE CRUSTACEA.

576. In these animals we find a class of articulata, in which the segments of the body are provided with articulated (jointed) limbs, or appendages. They are aquatic; only a few of them being able to support themselves, and that for a short time, on land.

577. Their breathing organs, or branchiæ, are organized for aquatic respiration.

578. In the highest individuals of the class, the Crab, and the Lobster, the external layer of the integument is hardened by the addition of earthy material, consisting of the carbonate, with a very small proportion of the phosphate of lime. In the smaller and lower Crustacea, the tegumentary covering retains a flexible, horny texture.

In a great proportion of the class, the body consists of twenty-one rings, of which seven are more or less soldered together to form the head, seven more enter into the formation of the thorax, and the remaining seven constitute the body. The great ponderosity of the skeleton of the lobster, by the deposition of such inordinate quantity of the Carbonate of lime, is essential to its well being, its great weight having the effect of keeping the animal at the bottom, notwithstanding the turbulence of the ocean. In these animals, the smaller claw is provided with two rows of pointed, sharp, cutting teeth, used as shears to divide its food; the larger claw, on the contrary, is furnished with two or three short rounded tubercles, and endowed as this claw always is with enormous muscular power, the instrument becomes a most efficient anchor.

579. The means of locomotion of a lobster in the water is prodigious; it expands the five plates, constituting the terminal portion of the body (or tail, as it is usually called), and by a single down stroke it is propelled a distance of from 16 to 20 feet!

580. The mouth in the higher crustacea is generally furnished with a pair of strong palpigerous mandibles, and five or more pairs of jointed under jaws, which move transversely, and support articulated feelers; the three outer pairs of under jaws are the largest, and support gills at their base.

581. The entrance of the mouth presents an upper lip, a bifid tongue, and sometimes an under lip. The mouth opens by a very short, narrow œsophagus into a capacious stomach (Fig. 207), provided internally with a great number of minute (microscopical) teeth; in addition to these, there are three very large calcareous teeth, situated near the pyloric orifice of the stomach, their external portion being remarkable for their redness.

In examining the external aspect of this stomach, the very short

FIG. 207.

External view, stomach of Lobster.

FIG. 208.

Stomach of Lobster opened to show gastric teeth in situ.

œsophagus (*b*) is seen to terminate immediately in the capacious digestive sac (*d*), at the upper portion of which a pair of short, strong jaws (*c*) are seen. A number of strong calcareous bones, longitudinal in their direction, support the membranous portion of the stomach, and form a solid basis for the support of the large teeth. The central rounded tooth (*b*, Fig. 208) is supported upon a large, somewhat triangular bone, transverse in its direction. The entire organ is covered externally with a layer of muscles of great power. The pylorus is shown at *a* (Fig. 207).

582. Two of these teeth (*a*, Fig. 208) resemble the grinding or molar teeth of an Elephant, whilst the third, which is placed in front, and somewhat below the former, has a rounded termination (*b*). The lateral teeth are employed to cut, divide, and comminute the food, which is performed by a rounding motion, like the action of one mill-stone upon another; the third tooth is employed in constantly pushing the food, as it escapes between the grinding teeth, back again, to be more thoroughly triturated.

The whole of this curious gastric apparatus (the three large teeth) constitute what is popularly called "the lady, in the head of the Lobster," and, when inverted, the rounded tooth personates "the lady," who is supported by the two lateral grinding teeth.

583. The alimentary canal passes, without convolutions, through the long axis of the body, and opens by distinct apertures at each extremity. The mucous coat sometimes forms folds in the œsophagus and stomach; the muscular layer is strongest at the orifices of the stomach, and there is no mesentery in the abdomen. The pyloric extremity of the stomach receives on each side a short and wide duct from the liver, but this part of the subject will be best understood by reference to the accompanying figure.

A longitudinal section of a Lobster (*Astacus marinus*) is given in Fig. 209. The under jaws (*a*), with their feelers, are placed on the inferior aspect of the head, between the large claws and the two pairs of antennæ.

Fig. 209.

Section of Lobster.

The short œsophagus opens into the stomach (*b*), which is surrounded by the numerous lobes of the liver (*n*, *n*). The intestine (*c*) receives at its commencement the two hepatic ducts, and passes beneath the heart (*e*); the posterior aorta (*h*) follows nearly a straight course to the vent, which is situate below the last segment of the body (*d*).

584. The anterior aortic vessel (*f*), and the pulmonary vein (*g*), are both distinctly seen.

585. In addition to the vascular system already described, consisting of the heart and arteries, there is yet another portion of the utmost importance, namely, *venous sinuses*.

586. Instead of veins, the blood is returned to the heart by these structures, which are large, loose sacs, the coat of which is of delicate transparency. The heart itself is enclosed in a venous sinus, and lies literally bathed in blood. These sinuses communicate freely with each other, and with the arterial system. The best way

to procure a minute injection of a lobster, is to put a pipe into a claw and pass the injection through it. The venus sinuses will fill first, afterwards the arteries and the heart.

587. If, in the ferocious combats to which the lobsters are always exposed, one happen to wound a claw of its adversary, the injured lobster instantly casts off the limb, always at a particular joint—at the *second articulation*. If this were not done, the animal would soon bleed to death, in consequence of the lacerated venus sinus. Cast off at the joint indicated, provision is made there, but nowhere else, for the perfect contraction of all the soft parts, and, as the lobster possesses the power of renewing lost portions of its structure, no permanent injury results.

588. The membranes composing the walls of these sinuses are of such extreme tenuity, that they can only be demonstrated by the aid of the injecting syringe; the most careful and accurate dissection fails to discover them.

LESSON XXXVII.

ORGANS OF NUTRITION IN INSECTS.

589. The intestinal canal of any animal is the tube which commences at the mouth, and is devoted to the reception of nutriment, whereby the growth and development of the individual may be promoted, and the wear and tear, and positive loss since the last meal, may be compensated for. In all the higher animals this canal possesses an opening at the opposite extremity; that this is not essentially necessary we have abundantly seen in relation to classes already discussed—*Infusoria; Entozoa;* many *Polypi;* the *Acalepha;* and *Asterias*, amonst the Echinodermata.

Examples of this condition are not wanting in Insects, but it rarely occurs, and is only met with in the infantile condition (larvæ, maggots), and never in the perfect insect.

590. This canal is subject to great modifications of distension and constriction, whereby it is separated into a variable number of divisions, and as the function of these divisions is dissimilar, they have received different names. In addition to the partition of the canal, there are peculiar processes, or appendages, which either originate from or open into it.

591. The intestinal canal of Insects consists of three membranes; the innermost membrane is smooth and textureless, and variously armed with horny lines, ridges, or teeth. It is most distinct in the pharynx, crop, and proventriculus, or gizzard.

The second layer is white and smooth, and, although usually thin, is sometimes thick and spongy.

The third (outer) layer is a compact, firm, fleshy, muscular coat; it is not equally observable in all parts of the intestinal canal, but is readily seen in the pharynx, stomach, and colon, but it is lost in the crop, or craw.

592. The length of the intestine in Insects appears to be governed by the same law that regulates it in other animals; those that feed on vegetable matter usually possess a longer and more distended intestine than those which feed on animal matter, in which it is shorter and narrower.

593. In this class the intestinal canal is divided into the *pharynx*, the *œsophagus*, *the crop, or craw*, the *proventriculus*, or *gizzard*, the *stomach*, the *duodenum*, the *ileum*, the *cæcum*, and the *colon*.

594. The appendages are the *salivary glands*, the *liver*, and certain vessels supposed to constitute a *kidney*.

595. The several parts enumerated are never all present in the same individual; sometimes one part is wanting and sometimes another. Thus, insects with a suctorial mouth have no need of a *pharynx;* neither do they possess *a gizzard*, for, feeding upon fluid food only, they have no need of such an organ. The part most usually deficient is the *duodenum*, which has only been found in some of the beetles; after this the *cæcum* is less usually found, as it belongs only to those insects which feed upon animal matter.

596. The biliary vessels are seldom wanting, the salivary glands frequently, and the kidneys very generally.

597. The Pharynx is the funnel-shaped commencement of the œsophagus, and is only found in *mandibulate* insects; it is of large size in grasshoppers, cockroaches, and most caterpillars.

598. The Œsophagus extends from the pharynx to the stomach; it is distinguished from the pharynx by its smaller capacity, and from the stomach, by its different structure. In the Lepidoptera (butterflies and moths) it is double for a space, and then united into one tube.

599. The separation of œsophagus from stomach is sometimes effected by a constriction; sometimes it passes insensibly into it, and sometimes the crop intervenes between them.

600. It has been remarked that the crop is absent in insects provided with a suctorial mouth, but all these possess a peculiar organ not found in other insects; this is, sometimes, a bladder-shaped distension of the œsophagus; in others it forms a distinct bag, which opens into the œsophagus; and in still another order it hangs appended to the œsophagus by means of a long, thin duct, frequently far in front of the stomach.

601. This organ is the *sucking*, or *pumping stomach;* its function does not consist in being a receptacle for nutriment, but in promoting the procuration of it, by distending at the pleasure of the insect, and by the rarefaction of the air contained in it, facilitating the ascent of fluids in the terminal proboscis, and œsophagus. But the action of this organ will be more fully explained hereafter.

602. THE PROVENTRICULUS, or gizzard, is the third division of the alimentary canal; it is a small, narrow, and tubular cavity, furnished with teeth, spines, or horny ridges. It lies in front of the mouth (or commencement) of the stomach; it is found in all insects prone to feed on hard substances, which require thorough comminution previous to digestion.

Externally it has a roundish or ovate appearance, and is more distinctly muscular than any other portion of the intestinal canal.

603. THE STOMACH is that portion of the canal which extends from the end of the œsophagus, or of the crop, or of the gizzard, to the opening of the evacuating ducts of the biliary vessels. Some authors call it duodenum, because digestion commences in it, but from the analogy of the higher animals it is probable that the stomach ends prior to the connection with the bile vessels, and that their secretion is poured into the first of the intestines proper. The subject, however, is open to doubt, especially as we find commonly in the bivalve, and other Mollusca, that the bile is poured directly into the stomach.

The divisions from the stomach are fewer and more simple than those which precede it; with the exception of the colon they are much narrower than the stomach, and more delicate in their structure.

604. THE DUODENUM.—When this intestine is present, it is separated from the stomach by a distinct constriction, which is probably a pylorus; immediately beyond this the bile vessels enter the intestine.

605. THE ILEUM.—Wherever the duodenum is wanting, the ileum follows immediately upon the stomach, from which it is also sepa-

rated by the pylorus. Sometimes this intestine is wanting, and in that case the stomach joins the colon.

606. The last division of the alimentary canal is THE COLON; it is usually divided from the preceding portion of the intestine by a valve, which completely closes its aperture. The colon is subject to great variety of form; it is found cylindrical, clavate (club-shaped), sac-shaped or longitudinally folded. The situation of the colon is always determinate—found at the apex of the abdomen, and surrounded by the last segments.

607. THE CŒCUM.—In many insects a blind, sac-shaped appendage is found in connection with the colon; this is the cœcum. Like the intestine to which it is attached, this is also subject to great variation in form; this portion of the canal is peculiar to the carnivorous tribes, although occasionally found in the butterflies. The exact function of this organ is not known in any animal, but (in conjunction with the colon) in the higher animals it is supposed to be as a second stomach.

608. THE BILIARY VESSELS.—These are narrow, filiform tubes, which open into the duodenum, if present, or the ileum, where the former is wanting; the ends not connected to the intestines are either free and closed, or pass into each other, and thus form one vessel, which pierces the intestine at both ends.

609. THE SALIVARY GLANDS.—These are various in form, number, and the situation where their secretion is poured. In some insects they are tubular, in others vesicular, and in another series lobulated. In some the secretion is emptied into the mouth, in others the proboscis, and lastly, directly into the stomach. Some insects have one pair of these glands, some two, and others (like the higher animals) three pairs. Illustrations of them will be hereafter given.

610. Before proceeding further, it becomes necessary to show the principles of classification of insects, which will render that portion of the subject very simple, which, without its aid, would be involved in great confusion. As the simplest, but by no means the best, the Linnæan system will be adopted.

611. This naturalist selected the structure of the wings, thence called the *Alary* (wing) system, as the basis of his classification; he had *seven orders*, the last being wingless.

In addition to the names of the orders, and translation of the Greek compound names, an illustration of the structure of the wings in each order is appended.

LESSON XXXVIII.

NUTRITION IN INSECTS, CONTINUED.

FIG. 210.

612. COLEOPTERA,

(*koleos*, a sheath; *pteron*, a wing.)

BEETLES.

FIG. 211.

HEMIPTERA,

(*emisus*, half; *pteron*, a wing.)

TREE-BUGS.

FIG. 212.

LEPIDOPTERA,

(*lepis*, a scale; *pteron*, a wing.)

BUTTERFLIES AND MOTHS.

FIG. 213.

NEUROPTERA,

(*neuron*, a nerve; *pteron*, a wing.)

DRAGON-FLIES.

FIG. 214.

HYMENOPTERA,

(*hymen*, a membrane; *pteron*, a wing.)

BEES, WASPS.

DIPTERA,

(*dis*, two; *pteron*, a wing.)

HOUSE AND FLESH FLIES.

FIG. 215.

APTERA,

(*a*, without; *pteron*, a wing.)

WINGLESS.

613. The structure of the mouth of an insect gives fair inductive evidence of the general conformation of the nutrimental organs, as there is a necessary connection between them.

614. The COLEOPTEROUS insects, or true beetles, whose delicate wings are covered and protected by strong, bony sheaths, or wing-covers, are *mandibulate*; that is to say, their upper jaws, or mandibles, are well developed, and offer the best type of structure of these organs. In the mouth of one of the predaceous and carnivorous Tiger beetles (*Cicindela hybrida*), Fig. 216, is the well-formed, slightly bilobed, upper lip (*a*); below, and on either side of it (*b*), are the formidable upper jaws (mandibles), in this insect furnished with a number of strongly formed teeth, the better to kill and divide its living prey.

The under portion of this mouth is shown in Fig. 217. The un-

FIG. 216.

Upper portion of the mouth of Cincindela hybrida.

FIG. 217.

Under portion of the mouth of Cicindela hybrida.

der jaws, maxillæ (*a*), are furnished with two pairs of auxiliary jointed appendages (*b*, *c*), which perform the function of hands in conveying food to the mouth; they are called *palpi*, or *feelers*, and are supposed to be endowed with much sensibility. The trilobate central piece (*d*) is the *lower lip*, to which is attached a long pair of jointed feelers, beautifully fringed with hair (*e*)—these are the *labial palpi* (*labium*, the under lip), and the chin is shown at *f*.

615. It has been remarked that those animals that subsist on animal food, have a short and simple form of the nutrimental organs: such is the case with the Tiger beetles; moreover, they are not subject to much convolution, but are found nearly straight.

616. A figure of the alimentary canal of *Cicindela campestris*, which is a beetle common in this country, and in Europe, is given (Fig. 218). The œsophagus is shown at *a*; it soon dilates into a

FIG. 218.

Alimentary canal Cicindela campestris.

FIG. 219.

Crop of Dyticus marginalis.

large crop (*b*), the surface of it being covered with minute follicles. This is succeeded by a small, but strong muscular gizzard (proventriculus), *c*, the interior of which is lined with teeth. The gizzard opens directly into the true stomach (*ventriculus*), also covered with follicular appendages (*d*).

At its lower portion the pyloric valve is placed, and in that neighborhood the biliary ducts (*e*) pour in their secretion; it is not quite clear, however, whether the valve be situated below these bile ducts or above them.

The intestine (*f*), commences beneath the biliary vessels, and terminates in a short, dilated colon (*g*).

In the large aquatic beetle, *Dyticus marginalis*, found as abundantly in the ponds of this country as of Europe, the crop is of large size, and terminates in a gizzard provided with four large triangular teeth (Fig. 219). The crop (*a*) is a capacious bag, its interior beset with very minute teeth, and deeply furrowed; the proventriculus, or

gizzard (*b*), and its four teeth, are seen just in advance of the commencement of the stomach. The crop is opened to show the teeth.

617. The mouth in the next order, *Hemiptera*, or the Tree bugs, has undergone remarkable modification—the whole of it is transformed. In place of well-formed upper and under jaws, we have only four delicate bristles; and these are so fine and fragile, that when not in use they require the protection of a sheath, which is specially developed for their preservation. The mouth of these insects is distinguished by the possession of a jointed organ called *the rostrum* (Fig. 221). This has from three to five joints. The organ itself is simply an altered form of the lower lip, which in these insects forms the sheath or protecting case alluded to.

Fig. 220.

Upper portion of mouth, Tree bug.

Fig. 221.

Rostrum of Tree bug.

The remainder of the apparatus of this curiously formed mouth is shown in Fig. 220. The upper lip (*a*) is a long, slender, somewhat triangular scale; its office, however, appears to be uncertain, the jaws being confined in the rostrum. The bristles representing the upper jaws are seen at *b*, and the lower jaws at *c*.

Frequently these organs terminate in a fine point; at other times their extremities are provided with cutting instruments, those of the first pair always differing from those of the second. Although organized to pierce the tough cortex (bark) of plants, these animals never refuse the more nutritive juices of animals if opportunity favor them, as every practical Entomologist knows to his cost, and the pain resulting from the bite of many of them is very severe.

618. The best known insect of this order, is the loathsome household tormentor, the common bug (*Cimex lectularius*), and a figure of its nutrimental organs is given (Fig. 222). The mouth receives the secretion of two pairs of salivary glands (*h*, *i*), in the form of simple follicles, terminated by minute vesicles (*i*).

Fig. 222.

Alimentary canal, Cimex lectularius.

The short œsophagus dilates slightly to form a very small crop (*c*), which communicates with a true stomach of some length (*d*). In this, as in the former instance, the true position of the pyloric orifice is by no means clear, but, either into the stomach, or immediately at the commencement of the intestine, the bile vessels (*g*) empty their secretion. The canal terminates in a short colon (*e, f*). The head is shown at *a*, the antennæ at *b*, and the rostrum at *k*.

619. The omnivorous Cockroaches (*Blattaria*) were erroneously included in this order by Linnæus; they now form a distinct order, under the name of *Dictyoptera* (*diktos*, to make lace; *pteron*, wing).

The nutrimental organs present many points of great interest; the preparation from which the figure was made (Fig. 223), remains connected to the head, the parts of which it is not now necessary to describe. The œsophagus (*a*) terminates in a large crop (*b*), at the terminal portion of which, eight (sometimes only six) large and strong gastric teeth are found (Figs. 224 and 225). The salivary glands are extensively developed (*c*), and show a number of lobules terminating in a lengthened sac, each gland communicating with its proper duct.

FIG. 223.

Nutrimental organs, B. Americana.

The crop has had a portion removed, to show the structure and folds of the mucous membrane; this is easily done, as the preparation is preserved in fluid.

620. Immediately below the proventriculus (gastric teeth), and at the commencement of the stomach, there are eight long follicles disposed around it, usually filled with a thick, white substance (*d*). These appendages in this situation are peculiar; whatever the nature of their secretion is unknown; but some authors suppose (with great probability considering the habits of the animal) that they are a second series of salivary glands, pouring out their secretion on the food the instant it has been duly and effectually comminuted by the gastric teeth. The stomach (*e*) begins where the last described follicles connect, and is a long, tortuous, convoluted tube, terminated by a distinct pylorus. The Ileum (*f*) succeeds the stomach, and receives the contents of the numerous short and slender biliary tubuli (*g*).

The large distended colon joins the ileum; after one convolution

it narrows to a size scarcely larger than the stomach, and slightly enlarges again, prior to its termination.

The gastric teeth (Figs. 224 and 225), are shown in two views of

FIG. 224.

Gastric teeth, Cockroach.

FIG. 225.

Gastric teeth, B. Americana.

FIG. 226.

Pavement epithelium of funnel-shaped cavity, B. Americana.

them. In the first (Fig. 224), the crop has been cut open, and the teeth seen in profile, whereby their entire figure is well shown. The central teeth show their toothed processes very distinctly; the lateral teeth are somewhat foreshortened, and not quite so perfect. It will be seen that the upper portion of these teeth is terminated by a long and strong toothed process; the lower portion also is indented, and toothed, the whole forming a most efficient apparatus.

Moreover, they are based upon and supported by a series of bones.

In Fig. 225, the spectator looks down upon the teeth, and into the funnel-shaped, valvular cavity beneath them. The teeth are seen at *a*; strong fasciculi of muscles between them at *b*, and the membrane which lines the funnel-shaped cavity, leading to the stomach, is thrown into a number of large rounded folds, *c*. This membrane is covered with a beautiful surface of minute pavement epithelium (Fig. 226).

FIG. 227.

Salivary glands, B. Americana.

621. A preparation, showing the salivary glands entire, is figured in 227. The lobules (*b*) are everywhere seen communicating by short ducts, with the large duct common to the glands on either side (*a*); the latter coalesce, and form a common duct which empties its secretion into the mouth (*c*).

LESSON XXXIX.

NUTRITION IN INSECTS CONTINUED.

622. The Linnæan order Hemiptera is, confessedly, an ill-arranged one; in addition to the Cockroaches, and other extraneous insects, the Grasshoppers, Crickets, and their congeners, were admitted by the illustrious Swede. These have been removed by modern Entomologists, but as the system here adopted is strictly Linnæan, if it be necessary to speak of these insects at all, it can only properly be done in legitimate connection.

623. These insects, called now *Orthoptera*, from the leathery structure of their wing cases, are all voracious vegetable feeders, and they present by far the best developed proventriculus of any insects known to us.

624. The œsophagus in Locusta viridissima, soon terminates in the crop (Fig. 228, *a*); at the lower portion this forms a kind of neck, filled with small teeth, which ends in the proventriculus, in these insects a distinct organ (*b*). It lies slightly imbedded at its lower portion in another digestive sac, which is transverse in its direction (*c*), and to which a plexus of fine tubes (*h*), like the biliary tubuli, are attached. To this succeeds the true ventriculus (stomach), which is usually narrow, and of some length (*d*). At its lower portion, beyond the pyloric valve, the biliary vessels are connected (*e*), and the intestine proper commences. This at first is a dilated sac (*f*), which becomes attenuated, and after a convolution ends in the colon (*g*).

FIG. 228.

Nutrimental organs, Locusta viridissima.

625. The salivary glands in *Locusta viridissima*, the house, and most field Crickets, resemble those of the Cockroaches, and are displayed at *i*.

626. The proventriculus is such a wonderful structure that it merits a distinct notice, and a more highly magnified view to show it (Fig. 229).

The preparation from which the drawing was made, was dis-

sected from the Mole cricket (*Gryllotalpa*) from Jamaica, a much smaller insect than the European species, but fearfully destructive. The specimen and its companions cost the proprietor of a farm there upwards of £60,000 sterling, $300,000, by the entire destruction of his crop of sugar cane.

Fig. 229

Proventriculus of Gryllotalpa.

Interiorly the gizzard is divided into six compartments, by means of six bones (*a*, *a*), which occupy the whole longitudinal length of the organ. Between every two of the bones are three rows of teeth, and of these, the teeth in the centre, or the central row, are the largest and most powerful. Outside of the large teeth are two rows, one on each side of them, and still more outside are other two rows. All the teeth in these several rows differ somewhat in their structure; in addition to these, there are large teeth above and below the rows, and to assist their action the external surface is covered with a muscular coat of extraordinary power. The entire number of teeth contained in this gizzard is two hundred and twenty-two. So great is their capability for tearing and minutely dividing every substance presented to their action, that they have been compared, most fitly, to the machine used in cloth-making, called "the Devil," for nothing can resist its action.

A still more enlarged view is given of the position of the bones (*a*, Fig. 230), and of one row of the teeth. The lateral teeth, described above, are here lettered *b*; the central row, including a large middle and two lateral teeth, are marked *c* and *d*.

Fig. 230.

Enlarged view of one row of the teeth, Gryllotalpa.

627. In the intestinal canal of man, and the higher animals, a vast assemblage of glands, of minute size and uncertain function, are found, some of them solitary, others aggregated. Their presence appears to be essential to the action of this portion of the canal.

628. The Ileum of the house-cricket (*Acheta domestica*) exhibits a wonderful development of similar glands. This intestine is dis-

played in Fig. 231, where the glands are aggregated. A more highly magnified view of two of these glands is given in Fig. 232.

FIG. 231.

Ileum of the House Cricket.

FIG. 232.

Iliac glands of Cricket.

629. There appears to be great similitude between the performance of nutrition in the vegetable feeding insects and the vegetable feeding ruminant quadruped. In both there are *four* distinct sacs, devoted to this function; in the insect, mastication is effectively performed by the wonderful gizzard; in the Ox, by the peculiarly constructed teeth. Saliva is abundant in both, and each possesses a magnificent display of aggregated iliac glands.

630. The food that is intractable, and yields its nutriment with difficulty to the herbivorous quadruped, is no less difficult and intractable to the vegetating insect, and both require an extraordinary adaptation of many organs to reduce it to subjection.

631. The next order, the *Lepidoptera*, presents an equally singular structure of its mouth; here the upper lip and the upper jaws are so minute as almost to elude detection. Of the three triangular plates presented at the upper part of the figure (Fig. 233, *a*), the central portion is the upper lip, and the upper jaws are of the same size nearly, and shape, on either side of it.

Fig. 233.

Mouth of Cynthia cardui (painted lady) Butterfly.

632. The Butterflies and Moths rarely feed at all; but when they do condescend to perpetrate such vulgarity, they manifest great indifference, hovering over a flower, still on the wing. At last, probably, they incline to take a mere sip of the delicious fluid found in the nectary, and for this purpose unfold, and make straight, their spirally wound under jaws (*b*), which, in some

of them, are of great length (two inches long). The end of this compound instrument is thrust deep into the coveted fluid, and almost immediately the creature is on the wing again; the sip has been taken, the appetite is appeased.

633. The structure of the under jaws, when made straight, is very curious.

Each one is *a hollow tube, and the junction of the two forms another*, so that the apparatus consists of three tubes. The outer surface is ringed, and each tube is really a tube and a half. To protect these important organs, a pair of inordinately large feelers are found connected to the lower lip—labial palpi therefore (*c*).

634. The œsophagus (as will be seen hereafter) is divided into two branches, each one of which occupies an under jaw, so that either might act independently of the other. The central canal, formed by the junction of the two under jaws, receives and transmits the secretion of the salivary glands; so that the *central tube* is used to insalivate the food which is sucked up by the two under jaws. The under lip is much larger than the upper, but of variable size.

Fig. 234.

Nutrimental organs, Pontia Brassica.

635. The alimentary canal of the Cabbage Butterfly (*Pontia Brassica*) is shown in Fig. 234.

636. The œsophagus (*a*), cut off below the bifurcation, receives the tube connected with the pumping stomach (*c*), and the food is received into the stomach (*d*). The salivary glands (*n*, *n*), in this insect, are simple filiform tubes.

Below the pylorus, the bile vessels are connected to the commencement of the Ileum (*e*); the former are very delicate, and of great extent (*k*).

The cœcum is seen (*g*) arising from the colon (*h*).

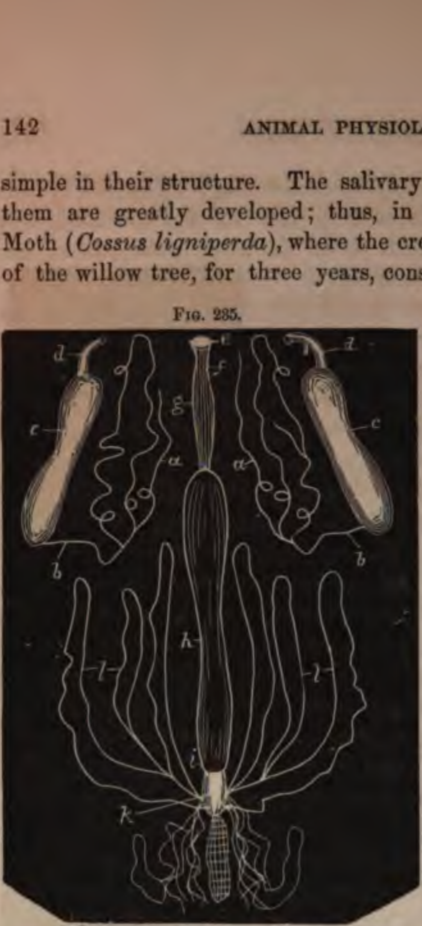
LESSON XL.

NUTRITION IN INSECTS, CONTINUED.

637. In the larval condition (maggots, caterpillars, and grubs) of insects, the nutritive organs are straight in their direction, and

simple in their structure. The salivary glands, however, in some of them are greatly developed; thus, in the caterpillar of the Goat Moth (*Cossus ligniperda*), where the creature is found in the interior of the willow tree, for three years, constantly feeding on the heart of the wood, large reservoir bags are added to the glands to hold a supply of this important secretion. The nutrimental organs of this insect are shown in Fig. 235. The drawing was made from a preparation, and to display all the parts the salivary glands had to be divided; they were placed, therefore, on either side the nutrimental canal.

Fig. 235.



Nutrimental organs, Cossus ligniperda.

638. The ramified tubular portion (*a*) at the lower part, is the secreting tube, or gland proper. They coalesce, and form one evacuating duct (*b*), which transmits the secretion to *c*, a large collecting or reservoir bag. At the summit of this bag is another tube (*d*); these combine to form one, and through it the secretion of these glands, and another pair, not present in the preparation, is delivered to, *not* the mouth, but to a little bony tube connected with the lower lip (Fig. 236), called *the spinneret*, found only in those larvæ which prepare a web for their pupa change.

639. The glands not present are of great length, extending from one end of the body to the other, and almost filiform; they are called *silk vessels*, and are supposed to originate this material. And this is true; but the saliva is always combined with it, as necessarily it must be when the four glands have only a common outlet.

640. When a Caterpillar is about to change into a Chrysalis, the salivary glands are painfully distended with a secretion that will no more be used for its legitimate purpose.

641. It is therefore poured out through the spinneret (in the

species possessing it), the gummy fluid becoming instantly inspissated when brought into contact with the atmosphere (Fig. 236), and forms a thread; during all this time the poor creature's body is sadly contorted, and it gives unmistakable evidence of great sickness, pain, and suffering. That the change the animal is about to undergo is really attended with such severe distress, is apparent from the fact that many of them die during the process.

FIG. 236.

Spinneret, Cossus ligniperda.

642. The alimentary canal (235) commences by a wide funnel-shaped cavity, the pharynx (*e*); to this succeeds the œsophagus (*f*), which dilates into a membranous crop, filled with deep longitudinal folds, by which means its internal capacity can be greatly increased (*g*). After the food has lain macerating here for a while, it is transferred to the long stomach (*h*), provided with a powerful muscular coat externally, and lined with a mucous membrane. Here the food is reduced to chyme, and allowed to pass through the pyloric valve (*i*) into the ileum (*k*), where it meets with the biliary secretion passed through the connecting gall ducts (*l*, *l*), and the *chyme* is transformed to *chyle*.

The Ileum terminates in a short, straight colon, which, as commonly happens, enlarges slightly, prior to its termination.

643. The liver exhibits a series of protuberances, which are alternate. A highly magnified view is given (Fig. 237), in which it will be seen that they are cells, each being filled with (apparently) globules, of an oily fluid.

FIG. 237.

Liver of Caterpillar, magnified.

The cut ends of this portion of the liver of a Caterpillar, have discharged an oil, which, in the preserving fluid, has assumed a globular form of variable dimensions, all of them being very much larger than when confined within the cells. This sacculated form of the liver is common to most insects, and may be regarded as characteristic; moreover, it is always minute and uniform, and cannot be confounded with the lobules of the salivary glands.

LESSON XLI.

NUTRITION IN INSECTS, CONTINUED.

644. The *Neuropterous* insects are, for the most part, *predaceous* and *carnivorous;* always killing their prey on the wing, they have hence been called "the Hawks amongst insects."

645. The most conspicuous insects of this order, and the best known, are the bold and beautiful dragon flies, or, as they are called in this country, "*Devil's darning needles.*" Furnished with a head almost all eyes, their sight is wonderfully piercing; provided with large, light wings, constructed of the most gauzy material, and abundantly supported by an incredible number of the lightest conceivable bones, their flight is as remarkable for its swiftness as their aim is unerring. It is a pretty sight to see these creatures Hawking over a pond, and remarkable the distance at which they see an insect—once seen, its death is certain! Our obligations are great to this order of insects, for they kindly free us from millions of pests, alike detructive of our property and sorely tormenting to our persons. It has pleased the Almighty dispenser of good to set up no end of antagonisms in nature—wherever a bane exists, there is the antidote; what a pity that man, in the plenitude of his ignorance, should take so much pains always to *destroy the antidote!* So important are these insects, it is not too much to say that he who wantonly kills a dragon fly commits a public wrong.

646. The smaller species of Libellula (Agrion), with a body less in diameter than a moderate sized pin, consume immense quantities of Mosquitoes, at the moment, too, when they emerge from the water and assume the winged state.

Fig. 238.

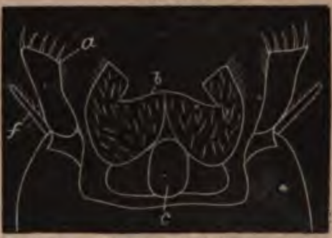
Upper part of mouth, Libellula.

647. The habits of other insects frequently change with a new form, but, whether as an inhabitant of the water, or a denizen of the atmosphere, the dragon flies are always cruelly carnivorous, and as such should be cherished.

648. The mouth of a Dragon fly is mandibulate (Fig. 238). The upper lip (a) is well formed, the upper jaws (b) are short, remarkably strong, possessing toothed processes, and supplied with muscles for

closing the mouth (*c*) of great power. The antagonist muscle (*d*) is simply required to open the mouth, and it is slight accordingly. The under jaws (Fig. 239) are short, and not very powerful (*a*); each is supplied with a small feeler (*f*), or palpus.

FIG. 239.



Under part of mouth of Dragon fly.

649. These organs are chiefly used as hands, to hold a living insect while the upper jaws kill and divide it, and afterwards convey the pieces to the mouth.

650. The under lip (*b*) is unusually large, provided with two processes with hinge joints, by means of which they can either be extended or remain closed; this apparatus forms a table, or platform, on which an insect can be placed while the upper jaws act upon it. Such an arrangement was necessary for an insect who kills and eats its prey on the wing. The *mentum*, or chin, is shown at *c*.

651. In the *Hymenoptera*, the mouth has undergone remarkable modification, especially in the Bees. These insects require strong, toothed jaws, for manifold purposes, and consequently their mandibles are constructed upon this type (Fig. 240, *a*). The upper lip is shown at *f*. But the great business of their lives is to procure the nectar from flowers, and convert it into honey, and for this purpose an especial apparatus is necessary. To this end, the under jaws, and their dependences (palpi), have become strangely metamorphosed; the under jaws (*b*) are formed into a tube to receive and protect the rest of the mouth when not required for use. Within these (*d*, *d*) are two long, jointed organs, gradually tapering upwards, with short terminal processes nearly at right angles; these are the maxillary palpi,

FIG. 240.

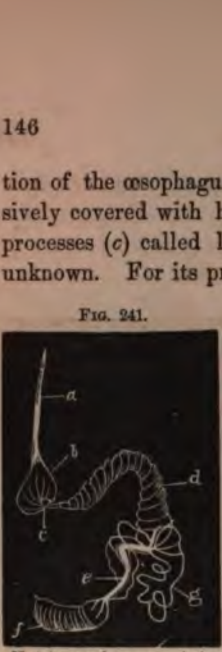
Mouth of the honey bee, Apis mellifica.

or feelers of the under jaws. Their function appears to be that of hands, to hold back the petals of a flower, whilst the long central tongue (*e*) is busily engaged lapping up the nectar; for this purpose they appear to be admirably adapted. The tongue (*e*) is much longer when extended than any other part of the mouth; it is perforated at its extremity, and has in its interior a canal, which is a continua-

10

tion of the œsophagus. The external surface is ringed, and extensively covered with hair. At the base of this organ are two little processes (*c*) called little tongues (paraglossæ), the use of which is unknown. For its protection, it folds up.

FIG. 241.



Nutrimental organs, Apis mellifica.

652. The structure of the nutrimental organs is very interesting (Fig. 241); the œsophagus (*a*) dilates into a large crop (*b*), or collecting bag, having one side of it particularly enlarged.

653. The pumping stomach is not developed in the Hymenoptera as a special organ, but its function is shared with the crop. The enlarged portion contains air; by removing the pressure of the muscles of the body, this air becomes rarefied, and if the other extremity, the tongue, be made air tight, as it must be when plunged deep into a viscid fluid, the tube, from the pumping stomach downward, becomes exhausted, and the fluid in which the tongue is placed necessarily ascends by a jerk. Then the action ceases, until the tube be exhausted again, which occurs directly the insect takes off the pressure by a deep inspiration, and so the action continues.

654. The valvular projection of the true stomach is inserted far into the crop (*c*) as a double tube, and must be withdrawn therefrom, when the Bee desires to feed upon the honey it has gathered; but so long as they remain within the crop that organ is merely a collecting bag, and retains the contents only until it can return to the hive, where it is cast up, and deposited in the cells.

655. During the period it remains in the crop, it is macerating in the salivary secretion, whereby its vitality is destroyed, and the probability of acetous fermentation obviated. From this moment it is preserved so effectually that it cannot decompose, in any time. So far as is known, honey is the only substance which, having been duly prepared in the stomach of the Bee, is cast up, and forms wholesome and delicious food for man.

656. The stomach (*d*) is a long, muscular organ, which gradually increases in size as it descends. Its lower portion is provided with a pyloric valve, below which the ileum (*e*) commences.

The bile ducts (*g*) empty their secretion at the commencement of the ileum, which terminates ultimately in the colon (*f*).

LESSON XLII.

NUTRITION IN INSECTS, CONCLUDED.

657. In the last order of winged insects, *the Diptera*, the mouth is again transformed; here we have a *proboscis*, or *Haustellum*, which is membranaceous, or more or less fleshy. It descends in a perpendicular direction from the orifice of the mouth, and is, in general, shortly from its origin, *kneed* (shaped like a knee) forward, and terminates in a flapper-shaped, suctorial surface.

658. In many of the predaceous Diptera (*Tabini*, *Chrysops*, *Stomoxys*, *&c.*), the bristles, or lancets lie, in a hollow groove excavated in the upper surface of the proboscis, and covered and concealed by a long corneous triangular scale, the upper lip. The *Mosquito*, *Flea*, and others, carry their lancets within a case, on the principle of the Hemiptera.

659. Many of the vegetable feeding two-winged flies, are pro-

FIG. 242.

Upper part of mouth, Helophilus tenax.

FIG. 243.

Fleshy under lip of Helophilus tenax.

vided with a mouth, in every respect similar to the *Tabini*, and their allies (Fig. 242).

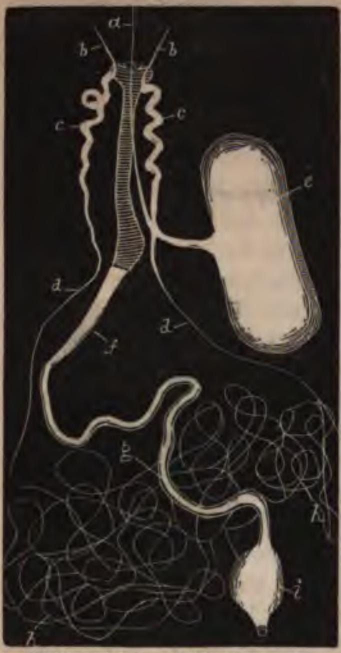
660. The mouth of the rat-tailed worm-fly (*Helophilus tenax*), to which Swammerdam did such ample justice, is a good illustration. The insect in its perfect state feeds only on ripe fruit, which it first stabs, or wounds, with its lancets, and then withdrawing them, places the expanded fleshy under lip over the wound.

661. These, moistened with saliva, firmly adhere by means of

their rugous (wrinkled) surface—the moisture contributing to make them air-tight. In all these insects, the under lip is modified to form the proboscis. The fleshy lips of the proboscis (*a*, 243), with their rugous surface (*b*), are seen partly spread out for attachment.

The lancets, &c., are shown in the figure 242. The long triangular upper lip (*a*) covers the remainder of the apparatus; on either side are seen the upper jaws (*b*), which are, in this insect, blunt-pointed: the under jaws (*c*) are curved like a scymitar, and remarkably thin, and sharp at their points. In the *Tabini*, and all their allies, the upper jaws are sharp, and lancet-shaped, while the under jaws are blunt, or probe-pointed. The long, leathery palpi (*d*) are merely for additional protection.

FIG. 244.



Nutrimental organs, Musca carnaria.

662. The pumping stomach attains its highest development in the Diptera; in them it constitutes an independent organ, which is beautifully exemplified in the nutrimental organs of the Flesh-fly (*Musca carnaria*), or Blue-fly. In this insect (Fig. 244), the long delicate œsophagus (*a*) is continued from the muscular crop, to the end of the proboscis, but not all the way as the œsophagus; a somewhat wider tube is excavated in the proboscis, at the commencement of which the ducts of the salivary glands (*b*, *b*), and œsophageal tube, proper, terminate.

663. The salivary glands (*c*, *c*), at their commencement, are robust, remarkably convoluted, tubes; by degrees they become straighter, and attenuated (*d*, *d*), and finally end as delicate tubes, parallel with the lower third of the stomach.

664. The course of the œsophagus is direct to the commencement of the crop, it then turns off, nearly at right angles, and ends in a bladder-shaped bag, of large size—the pumping stomach (*e*).

665. It is easy to understand that the small quantity of air, always found in this receptacle, becoming rarefied so as fully to distend

the sac, the tube in connecting with it becomes exhausted, and as the other extremity has been previously made air-tight, the ascent of fluid, as a sudden jerk, is inevitable. Of course its tendency is to rush into the pumping stomach, and if this could be achieved, death would most likely be the immediate result, as much as if a pail of water were suddenly poured into our lungs; but long before the air can reach the pumping stomach, reaction takes place, and the fluid is driven through a very short tube, nearly at right angles, but somewhat inclined to the œsophagus, into the crop, in whose callous margin a valve is placed to prevent regurgitation. Once in this organ, the food macerates in the saliva, and becomes subject to the action of its powerful muscles; in due time, it passes through a valve at the lower portion, and enters the stomach (*f*).

666. This latter is a very long, slender, tortuous, and convoluted tube, having (according to some authors) three distinct divisions in its interior; it terminates by a pylorus just before the commencement of the ileum (*g*), into which intestine the biliary ducts, as usual, enter. The liver (*h*, *h*) is of great size, and like the same organ in the Caterpillar, appears to be filled with oil cells, exceedingly minute, however. The ileum, too, is of unusual extent, but at length terminates in the Colon (*i*).

667. Thus, as briefly as circumstances would permit, the chief, and most remarkable characteristics of the nutrimental organs, and the adapting forms of the mouth in the Linnæan orders of insects have been described. It is unnecessary to speak of the *Aptera*, inasmuch as they really belong to the other orders, the want of wings being a sexual distinction; moreover, the majority of the individuals of this order were not Insects at all, and have been removed to the Classes to which they properly belong.

668. The structure of the nutrimental organs of insects is particularly interesting from the fact of their close agreement with like structure in the Vertebrate animals. Thus, the cœcal appendages around the pylorus of the Cockroach, bear close resemblance to a similar structure found in many Fishes; in the latter they are supposed to be salivary or pancreatic (pancreas, the sweetbread) in their secretion, and this is, at least, equally probable with the Insect. Feeding indiscriminately as the Blattaria do on whatever comes in their way, upon flesh, or fruits, vegetables, linen, clothes of all kinds, printed books and written manuscript, engravings or water-color paintings, old boots and shoes, and not unfrequently nibbling the toes (in hot climates) of persons while asleep, their power of digestion had need be very perfect to get quit of such heterogeneous matter.

669. The many digestive sacs of *Locusta viridisima* (large English grasshopper), and its allies, has its full representative in the four digestive cavities of the herbivorous quadruped. The only great and peculiar exception appears to be in relation to the pumping stomach of the *Lepidoptera*, *Hymenoptera*, and *Diptera*, but even this, in the opinion of some authors, but apparently with insufficient reason, is met by the air-bladder of fishes.

670. The persistency with which the glandular system is developed in insects, is no less remarkable.

Salivary glands, to the extent of even three pairs, is by no means uncommon, while few insects are entirely destitute of them.

The Liver is almost always found, and usually extensively produced, while in its ultimate structure (cellular) it bears great affinity with the same organ in higher animals. In none of the illustrations produced was a *kidney* found, but this organ is by no means rare.

Finally, in this class the most important problem, the ultimate structure of glands, may be studied with great ease. In the higher animals these organs are veiled by a parenchyma, which renders investigation difficult; but in insects, we find them already analyzed—existing as simple tubuli, and offering every facility for the most minute examination of them.

When the like organisms in man and the higher animals have been successfully treated, and reduced to their elemental condition, lo! they too, are simple tubes!

LESSON XLIII.

ORGANS OF NUTRITION IN ARACHNIDA.

671. The general characteristics of this class have already been given, together with the names of the orders into which it has been divided.

The Arachnidans are placed above the insects in the scale of being for the following reasons: they present a more concentrated condition of the nervous system, and of the heart; and the larger species possess a higher condition of the respiratory system, which is not only less diffused than in insects, but in some of them consists of *air-sacs*, or rudimental lungs. If a Spider be examined, it will be seen at a glance that the head is confluent with the chest, forming

the cephalo-thorax; the remainder is the body, so that it exhibits but *two* divisions; and this is equally true of all the members of this class.

672. Some of the lower Arachnida, so minute as to be quite microscopical, are parasitic on man, and the history of one of these parasites is not a little curious. It has already been observed that the human hair grows out of a bag, or follicle; this follicle receives the ducts of two fat secreting glands, called *sebaceous* glands.

673. Within the ducts of these glands, the parasite in question, *Demodex folliculorum* (*demos*, lard; and *dex*, a boring worm), is found (Fig. 245); in length, they range from the $\frac{1}{50}$th to the $\frac{1}{100}$th of an inch. The figure gives a magnified view of a hair-follicle (*a*), containing the bulb of the hair (*b d*), the sebaceous gland (*c*), and the

Fig. 245.

Demodex folliculorum.

Fig 246.

Demodex from the scalp.

Fig. 247.

Demodex folliculorum; the perfect animal magnified.

duct in which is the parasite (*d*). In adults, these creatures usually abound on either side of the nose; in young men, red pimples, of a painful character, appear on the forehead, face, neck, &c., which, when the inflammation subsides, is distinguished by a black spot. If this spot be tightly squeezed, a white, tortuous, somewhat spiral mass will appear—spiral, because a cast in solid fat of the duct—placed in oil, the fatty or sebaceous substance will separate and leave a specimen or more of the Demodex.

Another figure (246) is given, taken from the human scalp; *a*, the sebaceous glands; *b*, a hair; *c*, the ducts; and *d*, *d*, the parasites.

A highly magnified view of the animal is given in Fig. 247, where it will be seen that it possesses eight feet (*c*), like all the arachnidans.

674. The mouth (*b*) is furnished with a proboscis, and is therefore suctorial; it has also two short and thick maxillary palpi (*a*, *a*), consisting of two joints, and above is a narrow upper lip. The abdomen is minutely ringed.

675. No nutrimental organs have yet been discovered in these parasites, partly because of their opacity, and partly on account of the shining character of their integument.

676. The next parasite originates the most loathsome, disgusting disease that afflicts humanity—the itch. Many medical men have sought for this animal in vain, and hence they have concluded that no such creature exists in connection with the disease. But their failure has arisen from two causes: one, they have looked in the wrong place, and the other, the animal is too minute to be seen by unassisted vision, unless held up against the light. Usually they are sought for in the pustule, characteristic of the disease; but before the pustule can make its appearance, the Acarus has burrowed off in another direction, and to succeed in finding it, the neighborhood of the pustule should be explored with a needle.

677. The *Acarus scabiæi* (Fig. 248) possesses all the true characters of the Mites; the legs in some mites, terminate in suckers, but in this species (four of them) in long setæ (bristles *a*).

FIG. 248.

Acarus scabiæi.

678. The mouth has a twofold character,—it is adapted either for suction or mastication. The whole form of the animal adapts it eminently for the life it leads, constantly burrowing beneath the surface of the skin, where, having no use for visual organs, none appear to be present, as in the Mole.

The Spiders are a very interesting class of animals, the particulars in relation to them requiring more space than the limits of this work will afford; suffice it to say, that the organs of digestion are arranged on a very simple plan, as befits an animal strictly carnivorous.

The mouth, as compared with the same structure in insects, is also simple, and remarkably well adapted to the peculiar wants of the animal.

The short, strong upper jaws (Fig. 249) are provided with sharp pointed, slightly curved teeth (*b*), which are hollow, like the poison fang of a serpent, and for the same purpose—the transmission of the saliva.

FIG. 249.

Upper jaws of the Spider.

The instant a Spider bites a fly, or another individual of its own species, the saliva is poured out abundantly through the cavity of the tooth simultaneously with its insertion.

As a consequence, the victim is poisoned, the body swells considerably, and it dies immediately.

Now commences the process of feeding, which simply consists in sucking up the juices of the slain.

To assist this process, the base of the teeth (*a*) is provided with a double coronet of short, strong, pointed spines, upon which an insect is literally impaled, whilst the killing and feeding progresses. At the lower part of the jaws (*d*) two large cavities are seen, out of which the muscles were extracted.

The under jaws (maxillæ) are shown at *a* (Fig. 250), in the form

FIG. 250.

Under jaws, Spider.

of short strong organs, whose function it is to hold the insect, whilst the upper jaws kill it, and suck up its juices.

This operation is greatly assisted by the long, strong, five-jointed feelers (*b*, *b*), each of which terminates in a short hooked process (*c*). Surely no better form of apparatus could have been contrived to meet the special and peculiar requirement of a Spider.

680. In the domestic spider, the œsophagus (*a*, Fig. 251) passes beneath the brain, and expands into a stomach almost as broad as the sternum, which sends off a large cœcal process into the base of the maxillary palpi (*b*), and of each thoracic leg—ten cœcal appendages in all. A shorter diverticulum (a turning) is continued from the upper part of the stomach (*d*). Where the intestine

passes through the narrow pedicle of the abdomen, it is contracted; it slightly expands in its straight course (f) along that cavity, then contracts and forms two short convolutions (g), and communicates with a large globular cœcum (h) from which the last short intestine arises. Four bile ducts (i, i) open into each side of the straight portion of the intestine. Two long, slender tubes (k, k), constituting the kidney, communicate with the commencement of the cœcum.

FIG. 251.

Organs of nutrition, Spider.

681. There is a simple and easy mode of finding the class to which the articulata belong, at a glance: thus, if the body be divided into *three* chief portions, it is sure to possess just *three pairs of legs;* therefore the creature is an insect. But if *four pairs of legs* be present, this character is invariably found associated with another of great importance; that is to say, the body will have only *two divisions;* the head and the chest being soldered together to form the cephalo-thorax (*head, chest*), and the remainder constitutes the abdomen, or body. Here, then, we have the class *Arachnida* typified, and the specimen is either a Spider (the Greek name of the class), a Scorpion, or a Mite. If *five, six, or more pairs of legs* be present, again we find the two divisions of the body indicating the same parts as those already described (cephalo-thorax, and body), and these form the characteristics of the Crustaceous animals.

682. To descend still lower in the scale: if the specimen presented to our notice have a variable number of distinct rings, or segments, any one of which is like all the rest, and the legs numbering twenty-two, or more pairs, the specimen belongs to the class *Myriopoda*—many feet—to which the *Centipedes, Iulidæ, Wood-lice*, &c., belong. Size has nothing to do with it; the Mites (many of them microscopical specks) having the required characteristics, as much belong to the Arachnida as though they were as large as a Scorpion; and so of all the rest.

LESSON XLIV.

ORGANS OF NUTRITION IN THE TUNICATE MOLLUSCA.

683. The Molluscous, or soft-bodied animals, appear to be organized for the perfecting of the nutritive function, to the development of which every other consideration gives way.

684. The lower orders of this class (*Tunicata, Brachiopoda, Lamellibranchiata*) are headless, and called, therefore, *Acephala* (*a*, without; *cephale*, a head); those *with a head* are the *Pteropoda* (wing-foot), *Gasteropoda* (belly-foot), and *Cephalopoda* (head-foot).

685. The *Tunicata* are so called because their bodies are enclosed in a gelatinous membrane, or sac; they breathe either by a vascular membrane, or by a ribbon-shaped gill stretched across the common visceral cavity. There is no shell or calcareous deposit in these animals; moreover, in common with the headless Molluscs, they are fixed to the rocks, and other submarine substances

686. The *Brachiopods* (*brachion*, the arm; *pous*, the foot) possess a bivalve shell, have two long, spiral, strongly ciliated arms, developed from the sides of the mouth, and breathe by means of their vascular mantle.

687. The *Lamellibranchiata* are bivalve Molluscs, breathing by means of lamellated gills (hence their name) attached to the mantle. The Oyster and the Mussel are the best examples.

688. The *Pteropods* swim by two wing-like muscular appendages attached to the sides of the (supposed) head.

689. The *Gasteropods* are the slugs and snails; they walk upon a foot, of greater or less dimensions, attached to the under surface of the ventral surface—hence their name, *belly-foot.*

690. The *Cephalopods* have their locomotive organs attached to the head, generally in the form of muscular arms, or tentacles; this is the only order of the mollusca possessing an internal skeleton.

FIG. 252.

Muscular tunic, Cynthia pupa.

691. The Tunicatæ are frequently found in groups, forming compound animals, like many of the Polypes. The outer gelatinous tunic is

warty in many species, but is always found to be smooth and lubricous on its internal surface.

692. This tunic is lined by another, a muscular coat, of great beauty as regards the arrangement of its fibres (Fig. 252); in this animal (*Cynthia pupa*) the muscles consist of long diverging fasciculi, which originate from around the two orifices of the sac (*a*, *b*), and extend round the entire body of the animal. These fasciculi are attached to various points of the exterior tunic, but most intimately around the respiratory (*a*) orifice, and the vent (*b*), which are also provided with distinct and strong sphincter muscles (*c*, *d*), passing in a circular manner around them.

FIG. 253.

Nutrimental organs, Cynthia pupa.

693. The organs of nutrition in these animals are peculiar in their arrangement; thus, we find the mouth proper, or entrance into the nutrimental canal, placed at the bottom of the sac (*g*, Fig. 253); the food arrives at the mouth directly from the external respiratory aperture (*a*), being directed to it by the spiral respiratory current, caused by the vibratile cilia lining the respiratory sac. The mouth leads to an œsophagus of tolerable length, and ends in a well-formed, muscular cavity (*h*), sometimes folded longitudinally, and perforated at the pyloric extremity by the wide ducts of the biliary follicles (*f*, *f*).

694. Neither teeth, jaws, nor salivary glands, are found in connection with this very simple alimentary canal, but the liver is always found, under some follicular form, opening into the cavity of the stomach, as in other mollusca. The intestine forms a distinct curvature, in an upward direction, behind the respiratory sac; it terminates opposite to the vent (*b*), and ends with a margin of vibratile cilia, to compel, by their action, the discharge of efféte particles of matter.

695. The ovaria (*k*) and the oviducts (*m*) lie on the inner side of the intestine, the latter terminating by a margin of vibratile cilia,

Fig. 254.

Pyrosoma gigantium.

like the intestine, and for the same purpose—to compel the mature ova to pass through the aperture of the vent, when open.

696. In the beautiful and luminous *Pyrosoma* (Fig. 254) we have an interesting example of a compound molluscan group. The external tunics of the individuals composing this group, are thin, soft, very transparent, and of a bluish white color, and are the parts by which they appear to be united together.

697. The Pyrosoma is a long tube shaped like a finger, closed at the upper end (*a*), and open at the lower extremity (*b*), and composed of a great number of distinct individuals (*c*), which possess an internal organization similar to the Cynthia. Like the latter, they also possess two orifices, but their position is different; their respiratory apertures are placed on the sides of the long projecting papillæ (*c*), and the apertures constituting the vents of all the separate individuals, open into the interior of the tube; so that, solely by the combined act of respiration, this elegant tube is carried through the seas.

The species of this animal common to the Atlantic (*Pyrosoma gigantium*), is of about the length of two fingers, and when seen on a still night, or, better still, if captured and conveyed in a basin of sea-water into a cabin, is an object of remarkable beauty.

LESSON XLV.

NUTRITION IN THE BRACHIOPODA.

698. There are only three orders of this class, the *Lingula*, *Orbicula*, and *Terebratula*. These are all protected by shells, and attach themselves to foreign substances, the Lingula (so called because tongue-shaped) by means of a very long peduncle (Fig. 255 A), which passes between the two valves: *a*, the shell, *b*, the peduncle; and the *Terebratula*, by a much shorter peduncle, which projects through a hole in a beak-shaped prolongation of one of the valves.

699. In the latter the alimentary tube is very short, of great simplicity, and confined to a small space. The rest of the interior of the lobes of the mantle is occupied by three long, strongly ciliated arms, disposed in folds and spiral curves. The bases of the arms

join, and form a transverse fringed band above the mouth; the bent portions of the fringed arms are supported by slender, elastic, calcareous processes.

700. A figure of the nutrimental organs in situ is given (Fig. 255). The peduncle (*e*) for attachment is seen in connection with that layer of the mantle that forms the back; a double heart is said to exist in these animals, the auricles of which (*b*, *b*) are placed on either side of the alimentary canal, and above the point of junction of the curled arms. It is, however, most probable that the so-called "hearts" are simply the external openings of the ovaria, by which the ripe ova effect their escape. The stomach is entirely concealed

FIG. 255 A.

Lingula, natural size.

FIG. 255.

Nutrimental organs in situ, T. Australis.

by a mass of biliary follicles (*c*), which completely cover it; above, it is covered with peritoneum. The intestine (*d*), which takes an oblique direction, is not very conspicuous, owing to its depth; two of the arms, fringed with strong cilia (*a*), are seen on either side, and in front the remains of the third arm (*a*), the curl having been cut off, to show the other parts of the structure. Another, a side view of *Terebratula Australis*, is given in Fig. 256; here the right (lower) arm is partly seen, being concealed by the great curl usually

assumed by the central arm (*e*). To the right of the figure is seen a large orifice—the tubular portion of the *left* arm, which has been removed. The anterior and posterior portions of the mantle are external in each direction (*f*). The trumpet-shaped mouth (*a*) is seen just below the tendinous portion of one of the four strong muscles (*b*), whose function it is to close the valves, and, crossing it obliquely, a muscle of the second pair; the white, glistening character of the tendons of these muscles is very beautiful. The mouth leads to a pharynx, and a very short œsophagus, which instantly terminates in the stomach. The biliary follicles (*c*), as before seen, completely

FIG. 256.

Terebratula Australis, side view.

FIG. 257.

Alimentary canal, Terebratula Australis, front view.

conceal the stomach, and the short, trumpet-shaped intestine (*h*) may be traced to its termination within the mantle. The peduncle for attachment (*g*) is seen as before.

701. A better view of the alimentary canal is given in Fig. 257, from a preparation of these organs dissected out of the body. Here the mouth is seen surrounded with short, unusually strong cilia (*a*); living and breathing under the weight and pressure of from *sixty to ninety fathoms* of water, the cilia of the arms require to be strong to compel the necessary currents of water to perform the circuit of the interior of the valves; charged with oxygen, for the supply of the respiratory organs, it is, at the same time, laden with food (ani-

malcules) for the supply of the animal's wants. To obtain this food from the strong stream of water constantly being propelled through its interior, the mouth has need of a special arrangement of ciliated processes, which are found accordingly. The funnel-shaped pharynx (*b*) is well shown in this view, and leads to the œsophagus (*c*); as before, the biliary follicles (*d*) obscure the stomach. The reverse side of this preparation (Fig. 258) shows the stomach (*d*), and the whole of the short intestinal canal (*b*), the mouth (*a*), and the biliary follicles (*c*).

FIG. 258.

Back view of alimentary canal, T. Australis.

FIG. 259.

The arms of T. Australis.

Another preparation has been copied, to show the disposition of the unmutilated arms, with their central one curled, and all of them armed with remarkably strong cilia (Fig. 259). These are additionally supported by a pair of strong calcareous (carbonate of lime) bones, which are placed on either side, lying between a double membrane, and just within the margin of the strong cilia.

The aperture at the upper portion of the figure passed around the œsophagus, which had to be dissected out of it. The nervous ring which surrounds the œsophagus, and distributes branches to the arms, is found in this situation.

LESSON XLVI.

NUTRITION IN THE LAMELLIBRANCHIATA, AND IN THE PTEROPODA.

702. In the common Oyster, the visceral mass occupies about half the cavity of the shell next the hinge. The rest of the space be-

tween the lobes of the mantle, being almost entirely occupied with the branchial laminæ (gills), which are four in number, equally divided, and placed on each side of the visceral mass. The mouth is furnished with two long, tapering, fleshy tentacula (*a*, Fig. 260), and is continued by a short œsophagus to an expanded stomach, into which numerous ramified hepatic follicles empty themselves (*b*). The intestine (*c*), after describing a remarkable convolution, ascending to the upper part of the stomach, which it crosses, is continued along the interspace of the branchiæ towards their extremities which are farthest from the mouth, where it terminates. The ovarium surrounds the intestinal convolutions, and forms, with the liver, the chief part of the visceral mass.

FIG. 260.

Nutrimental organs, Oyster.

PTEROPODA.

703. In all the Mollusca provided with a head, the capability of locomotion is always considerable; whereas in the acephalous (headless) molluscs it forms the exception—not the rule.

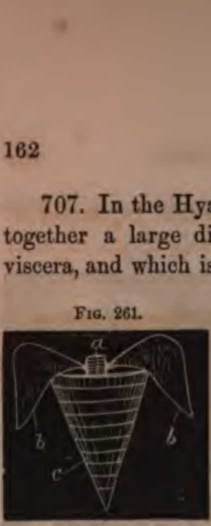
704. The *pteropods* are provided with two fin-like muscular expansions, attached to the sides of the neck, which, from their resemblance to wings, suggested *pteropoda* (*wing-foot*) as the name of the class. Some of these animals are provided with a light and delicate semitransparent shell.

705. In the *Hyalæa*, it resembles a bivalve shell, of which the two valves have been cemented together at the hinge, leaving a narrow fissure in front, and at the sides. In *Cleodora*, the two plates of the shell are united together along the sides, as well as at the base, leaving an opening only in front. Some (*Clio*, and others) are naked, or unprovided with shells.

706. All the pteropods are of small size; they float in the open sea, often at a great distance from shore, and in latitudes that suit them they swarm in such incredible numbers, as to discolor the sea. The huge whale, with its remarkably small œsophagus, chiefly subsists on the *Clio borealis*, and *Limarcina*, both of which species abound in the northern seas.

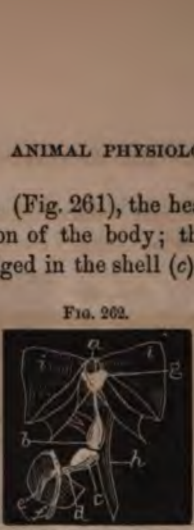
707. In the Hyalæa (Fig. 261), the head (*a*) and fins (*b*, *b*) form together a large division of the body; the portion containing the viscera, and which is lodged in the shell (*c*), constitutes the abdomen.

FIG. 261.



Hyalæa, in its shell.

FIG. 262.



Nutrimental organs of Hyalæa.

708. The mouth is a small longitudinal fissure (*a*, Fig. 262) at the apex of two diverging eminences; it contains a tongue covered with a thin, horny plate. There are no salivary glands in this species, but they are found well developed in the Clio. In both these animals the narrow lengthened œsophagus, which passes under a broad crerebral ganglion (*g*), and dilates in the abdominal cavity into a membranous crop (*b*), is slightly marked internally with longitudinal plicæ (folds). This first digestive cavity opens directly into a short cylindrical muscular gizzard (*c*), likewise marked with longitudinal folds on its inner surface, and lying, like the crop, over the great retractor muscle (*h*), by which the animal draws its head and fins (*i*, *i*) into its shell. From the muscular gizzard, the long narrow intestine (*d*, *e*, *f*) makes a double turn round the lobes of a small liver, and continues nearly of uniform thickness to its termination on the right side of the neck, under the right branchial fin.

LESSON XLVII.

NUTRITION IN THE GASTEROPODA, AND CEPHALOPODA.

709. In the lower Gasteropods, the respiratory organs are exposed, some on the back (Eolis), or the sides of the back; some at the lower part of the body, between the foot and the mantle; and some around the body, as in the patella (Limpet).

710. A figure is given of *Eolis Inca* (Fig. 263), in which the back is nearly covered with a series of respiratory sacs.

711. The greater variety in the food, and habits of life of the Gasteropodous Mollusca, renders a more complicated and varied form of the nutrimental organs essentially necessary. Thus, the

land species (*Snails* and *Slugs*) feed on the nutritive vegetables of the earth; many of the marine kinds (*Doris, Eolis, Tritonia,* &c.)

FIG. 263.

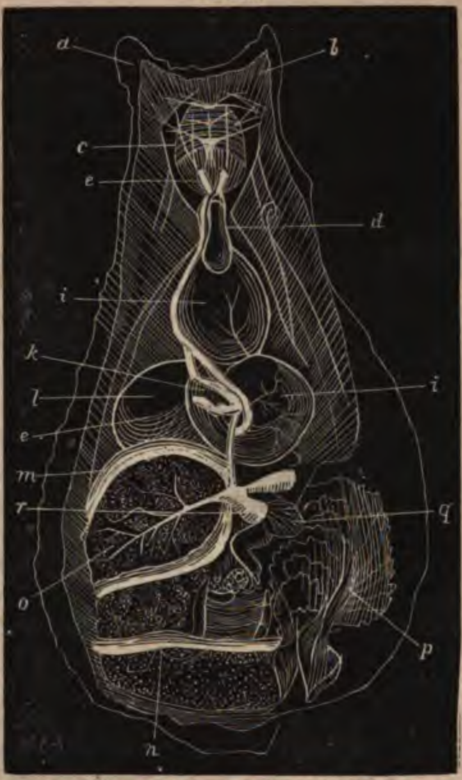
Eolis Inca.

on the lowest fuci of the Sea; whilst many others are carnivorous, and feed on living prey.

712. The *Aplysia faciata* feeds on coarse marine plants, and like the herbivorous quadrupeds, presents a complicated condition of the alimentary apparatus. The broad labial tentacula (*a*, Fig. 264) are moved by strong muscular bands (*b*). The lips are supported by two cartilaginous (gristly) laminæ (or plates), and the tongue is covered with minute recurved teeth.

713. The wide muscular cavity of the mouth (*c*) receives the terminations of two salivary glands (*e*). The short, narrow œsophagus (*d*) dilates into a large membranous crop (*i*); this crop, or paunch, occupies the right side of the abdomen and opens laterally into the smallest, middle stomach (*k*), which is provided internally with numerous

FIG. 264.



Nutrimental organs, Aplysia faciata.

broad, flat, horny teeth, which serve to divide the softened vegetable matter transmitted in small portions from the first stomach.

714. The third cavity (*l*) of this complex series of stomachs, is placed on the left side of the abdomen; it receives by several wide ducts, at its pyloric orifice, the secretion of a large, lobed liver (*o*), and of a long, single pancreatic follicle; its inner parietes are furnished with several sharp, horny spines, to assist in subdividing the coarse food, for the purpose of admitting the solvent gastric fluids. The intestine (*m*) forms several convolutions round the liver (*o*), and after a lengthened course, without forming an enlargement, it opens on the right side (*n*), near the posterior portion of the body, and immediately behind the heart (*q*, *r*) and the large gills (*p*).

715. In some of the Gasteropodous molluscs (as we have seen), there are as many as four distinct gastric cavities; horny teeth are more or less found in the interior of one, or more, of these sacs, in addition to the armature of the tongue, by teeth of various shapes and sizes, which obtains extensively in this class.

FIG. 265.

Teeth on the tongue of Buccinum undatum (Whelk).

716. A figure of the teeth of the tongue of the common Whelk (*Buccinum undatum*) is given in Fig. 265. In the Limpet, the tongue is longer than the whole body, and is covered with transverse rows of sharp recurved spines, by which they are enabled to file the coarse marine plants, on which they subsist.

CEPHALOPODA.

717. These animals, for the most part, are free, naked, and predaceous; they are provided with powerful organs of prehension, and mastication, and their short alimentary canal is furnished with highly developed salivary, biliary, and pancreatic glands. The muscular bulb of the mouth contains, in the naked species, two strong, curved, sharp, horny mandibles, very like those of a parrot.

718. The short muscular tongue is covered with rows of sharp, horny, recurved spines (as already noticed in other molluscs), attached to a cartilaginous base. There are two pairs of salivary glands; an upper smaller, and an inferior larger pair—both of which are conglomerated (*a round mass—a ball*), and lobulated (*composed of lobes*).

719. In the Nautilus, a short pharynx (*a*, Fig. 266) leads to the œsophagus (*b*), which dilates into a crop (*c*), with well marked longitudinal folds. Below this first cavity (*c*), a narrow tube conducts to the second stomach, or muscular gizzard (*d*); this is situated on the right side, and varies in its form, muscularity, and relative size, and is provided with a thick, tough, coriaceous internal lining, to protect it from the hard shells, and other dense substances taken in with the food.

FIG. 266.

Nutrimental organs, Nautilus.

720. The muscles of the gizzard radiate from around a circular tendinous part on each side, or pass continuously over the sides of the cavity.

From the left side of the gizzard a passage, generally short, and wide, leads to the third stomach (*e*), which in many Cephalopods has a convoluted spiral shape, and presents internally numerous transverse folds of its mucous coat.

Passing to the left side from the third, or spiral stomach, the intestine (*f*) forms a short single convolution near the left branchial heart, then ascends along the fore part of the liver to terminate between two longitudinal strong muscular bands near the base of the syphon, by a free external orifice (*g*).

721. This third gastric cavity forms (in *Nautilus*) a globular sac, plicated internally, with parallel folds. The intestine forms a short, single convolution directed downwards, then ascends to the fore part of the liver, to terminate between two strong muscular bands, near the base of the syphon.

722. Destitute of a shell, as the great majority of the Cephalopods are, they are left (apparently) without the means of protecting themselves from the thousands of foes, ever ready to destroy them.

723. Their naked, plump, soft, gelatinous bodies, offer an irresistible temptation to every fish that swims the ocean; to Lobsters and Crabs; and to nearly every marine animal.

724. The wisdom and beneficence of an all-wise Providence is singularly exhibited in favor of the Cuttle-fishes, for he has given them a passive means of defence, vastly more efficacious and superior than physical power, or great warlike capabilities: he has simply furnished them with a bag, full of intensely black ink; if pursued by an enemy, for even the shortest space, the creatures at once discharge the contents of this bag, which instantly renders the ocean, for a great space above, below, and around, exceedingly black and turbid,

—moreover, it affects the eyes of other animals: in the meanwhile, the Cuttle-fish escapes!

725. The situation of this bag differs in the various species, but it is usually found adjacent to the liver.

726. The beautiful black pigment known as "Indian Ink," is made by the Chinese from the inspissated (hardened) contents of the ink-bag of one species, and the no less beautiful color, Sepia, from the ink-bag of another species of Cuttle-fish, so that the Fine Arts are greatly benefited by the means necessary to insure their lives.

727. But the most surprising fact in this connection is, that the contents of the ink-bags of a number of *fossil Cuttle-fishes* has been made into an ink (in England), and the frontispiece of a pamphlet that went through a very large edition, printed with it; in color, it bears a close relation to Sepia.*

728. The Cuttle-fishes being shell-less, require a bone of some kind for the attachment of their strong and powerful muscles, and to give general support to the body. For these purposes, they are provided with an internal skeleton—the only animals amongst the invertebrate (save certain polypes) similarly provided. This bone, which extends nearly the whole length of the body, is called *the gladius* (a sword), and is as varied in form as composition.

729. In some species it is long, and shaped like the feather of a bird, the quill portion being inordinately long, whilst in substance it is scarcely cartilaginous. In the common Cuttle-fishes (*Sepia officinalis*), it is thick, and broad in shape, having its animal membrane consolidated by the carbonate of lime.

730. The bone of this animal is common in every Chemist's shop, and (in this country) is placed in the cages of Canary and other small birds; considering that it is solidified by an earth so weighty as carbonate of lime, it is, above all things, remarkable for its extreme lightness; we will see what causes it.

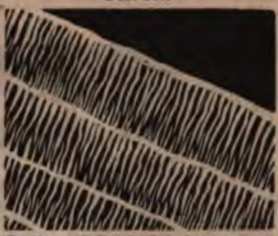
731. Take a portion of such a bone, break it, and place it under the microscope—the secret of its lightness will soon be revealed.

It will be seen that the structure consists of a number of strata, or laminæ, of inconceivable thinness; these are separated from each other by a vast number of pigmy pillars (Fig. 267), which necessarily admit of a current of air to pass freely between the laminated plates, which not only imparts lightness to the fabric, but must give great buoyancy to the animal.

* The Author possesses a copy of the pamphlet in question.

732. It is an inconceivably pretty sight to see a Cuttle-fish *blush*; blushing is by no means limited to them, for other naked (shell-less) molluscs do the same occasionally, but in an inferior degree. When one of these creatures is brought on deck from a dredge, and placed in a dish of sea-water, after a few minutes the whiteness of its skin will disappear, and its entire body and tentacles become suffused with a pale pink color, which gradually becomes somewhat intensified:—this is the blush.

Fig. 267.



Section of Cuttle-fish bone, magnified 100 diameters.

Left to itself, the animal will soon resume its former color; it is, however, easy to kill them preserving the blush permanently in death.

LESSON XLVIII.

NUTRITION IN FISHES AND REPTILES.

733. For the most part, these animals are predaceous, and swallow their prey entire; their œsophagus is consequently short and wide, their stomach capacious, and their intestine short.

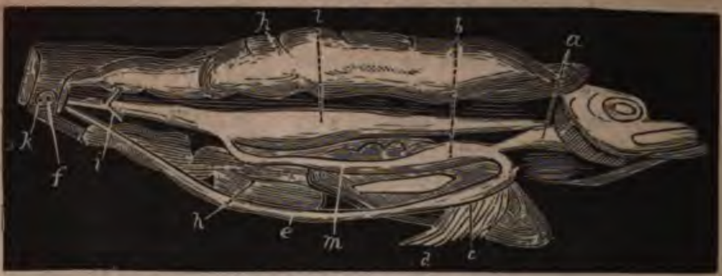
734. Their accessory glands are moderately developed, and their teeth are adapted to prehension rather than mastication; of the structure of these organs, more will be said hereafter.

735. The alimentary canal of fishes is generally more short and simple than in higher vertebrata, which agrees with their predatory habits, and their inferior position in the scale of being.

736. With a short œsophagus and a capacious stomach, with its two orifices approximated, the whole digestive canal of fishes is often shorter than the body, as seen in the common Herring (*Clupea harengus*), Fig. 268, where the narrow cardiac part of the œsophagus (*a*) opens into a lengthened tapering stomach (*b*), communicating by a long duct (*m*) with a large air-bladder (*l*). The duodenum, *c* (twelve; so called because the human duodenum is about twelve fingers in length; it is the first of the small intestines), is provided with numerous pancreatic tubuli (*d*), which remind us of the eight similar follicular appendages beneath the crop in the Cockroaches.

From this point, a short intestine (*e*, *e*) arises, which opens into the cloaca (*f*). The soft roe (*h*, *h*) of the male fish, like the ovarium of the female, empties its contents through the common duct (*i*), and

FIG. 268.



Nutrimental organs, Herring.

finally by the aperture (*k*) beyond the cloacal outlet (*f*). This one figure is a sufficient demonstration of the general arrangement of the nutrimental organs in the class of Fishes; the modifications to which it is subject being too unimportant to need comment: we therefore proceed to the class of

REPTILES.

737. These animals, like the Fishes, are predaceous in their habits, and swallow their prey whole. They have loose and feeble articulation of the jaws, which greatly favors such proceeding, while their teeth are sharp, slender, and fitted as prehensile organs, but ill adapted to the purposes of mastication.

738. The long, free bifid tongue of the Frog, covered with papillæ, and muciparous (mucous) follicles, is the all important instrument for the procuration of food.

739. It is attached by its apex to the inner surface of the under jaw, the base being loose and free in the back part of the mouth. A Frog will never touch any save a living insect, and of this fact it requires such positive and conclusive evidence, that the latter often escapes before the former is sufficiently stimulated to attempt its capture.

When once a Frog fixes his eye on a lively living insect, his whole appearance is suddenly changed. The passive, sluggish animal of the minute before, has suddenly assumed the aspect of ferocity.

740. If it be a fly at some distance from the frog, on the carpet, the latter, his eyes full of malignity and craft, stretches out his

limbs to their utmost capacity, and creeps towards the insect in the most stealthy, noiseless manner possible; as soon as he arrives within a certain distance of his victim, the tongue is thrown out so rapidly that it escapes detection; but the fly has been struck, glued to the tongue by the mucus on the surface, and returns with it into the Frog's mouth.

741. The senses of hearing, sight, and smell, are wonderfully acute in these animals. No one would believe that a fly alighting on the surface of a carpet, would be accompanied by any appreciable sound, and (so far as our sensations are concerned) this is quite true; not so with a frog, however; the fly may alight at a distant part of the room, and the frog's back be turned from that direction, yet he hears it instantly, turns round, and proceeds to effect its capture, in which he very rarely fails!

742. The mode by which a frog is enabled to seize its prey, is in this wise: stimulated by the sight of it, the tongue becomes injected with blood, through the influence of the imagination, until it is quite turgid or erect; at this instant, it can be thrown out and used. The action is like letting the back of the hand fall quickly from the elbow-joint, without moving the wrist, and allowing it quickly to rebound.

743. The process requires to be swift, for the breathing of the frog is suspended so long as the mouth remains open.

744. There is not in nature a more harmless or valuable animal than a frog, nor one, whose presence in gardens should be so much encouraged, for they consume only insects, spiders, and slugs, and the quantity of these they destroy is quite incredible.

FIG. 269.

Teeth and Palate of the Frog.

745. It has been remarked that the teeth have a prehensile character in the frogs, but this cannot be demonstrated in Fig. 269, copied from a minutely injected preparation of the palate of a frog, because the spectator looks directly down upon the teeth, whereby the pointed apices escape detection; moreover, he desires to see the blood-vessels, to do which, cuts off (apparently) the points of the

teeth. The teeth (a, a) are seen in their sockets, but so slightly attached that many of them are missing; neither is their sharp, pointed character conspicuous, being concealed by Canada balsam. The injection has run so minutely, that the pulps (b, b) of many of the teeth are injected. Two eminences may be seen to the right; these are the palatine bones, and to each, three and four teeth are articulated; in the frog the teeth are confined to these bones and the upper jaw. The beauty of the vascular (vessels) arrangement of the mucous membrane of the palate, need not be insisted on.

746. The strong muscular œsophagus is short, dilatable, and longitudinally folded; it leads to a narrow, elongated stomach, placed transversely from left to right, with thick, fleshy sides, especially at the pyloric extremity, and covered above by the two lobes of a large liver, always provided with a free and distinct gall bladder.

747. Injected, opened, and microscopically examined, the stomach of a frog presents all the elements of a true digestive cavity. Its mucous membrane is traversed with capillary blood-vessels, which ramify on the surface of the cell-walls, everywhere conspicuous (Fig. 270). Mucus issues from the cells, and a gastric fluid is secreted by the capillaries of the mucous membrane, so that the resolution of the food is accomplished on precisely the same principle in a frog as in a man.

748. The duodenum is remarkable for the entire absence of papillæ (*papilla*, a teat or nipple), but it is provided with transverse folds of the intestine, called *valvulæ conniventes* (valvular folds). These valvular folds have edges like papillæ, but, instead of being distinct bodies, stretch across the intestine as one single fold.

Fig. 270.

Stomach of Frog.

Fig. 271.

Duodenum, Frog.

749. This is shown from the injected duodenum of a frog (Fig. 271). The villi (or papillæ) of the duodenum, that we look in vain for in the Frog, present themselves with all their characteristics well developed, in the duodenum of the Toad (Fig. 272).

The same short, broad, square-shaped organ that belongs persistently to this portion of the intestinal canal in all the warm-blooded animals, is equally characteristic of the duodenum of a lowly Batrachian!

The folds that were transverse in the duodenum, become longitudinal in the ileum, and display a beautiful arrangement of capillary blood-vessels (Fig. 273), as shown in the figure, copied from an injected preparation of the tissue. The large intestine (colon), although destitute of folds, presents a fine example of capillary distribution, and is shown in Fig. 274.

FIG. 272.

Ileum of Frog.

FIG. 273.

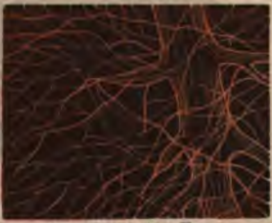
Duodenum of Toad.

The mucous membrane of the large intestine presents great uniformity in both frogs and toads, and consists of a plexus of capillary blood-vessels, which appear to cross the larger vessels of supply and return (arteries and veins) which are situated in the sub-mucous tissue.

The mucous membrane is so thin and transparent in these animals, that the larger vessels can be distinctly seen in a well-injected preparation, through its parietes; this is shown in the large intestine of the Frog, Fig. 274.

750. The Batrachian reptiles (*batrachos*, a frog), which include the frogs and toads, *are not amphibious*—they are air-breathing animals, and cannot respire at all under water. If a frog be kept beneath the surface of the water he dies, in not exceeding four hours.

FIG. 274.



Large intestine, Frog.

751. There are reptiles, however, supplied with permanent gills, for aquatic respiration, and lungs, for breathing air, and these constitute truly amphibious animals. The ponds of this country teem with a very interesting amphibious reptile—the *Menobranchus* (permanent gills), usually called "the mud sucker."

752. In form it is somewhat Lizard-like, having a long body, four

short legs, and a tail of moderate length. Its head is broad and flat, at the base of which the "permanent gills," from which its Greek name is derived, are seen on either side.

753. Its internal structure agrees, in general particulars, with the frogs; the stomach marks a slight advance in relation to the great regularity and distinctness of the mucous cells, and of the deep-seated

FIG. 275.

Stomach of Menobranchus.

FIG. 276.

Ileum of Menobranchus.

capillaries (Fig. 275); so, too, the ileum (Fig. 276) shows the longitudinal folds, and the capillary arrangement in great perfection.

754. Another of these Amphibiæ, the *Menopoma* (permanent holes), like the former in size and general particulars, but presenting a series of holes at its sides, like a Lamprey, and not yet found in this country (so far as known), but indigenous to Africa, presents a still further advance in the structure of the stomach (Fig. 277), by displaying in each cell two mucous tubes.

755. It is deeply interesting to trace the gradual development of such an important organ as the stomach, from its condition in a batrachian reptile up to man, and this principle will be followed (as far as expedient) henceforth.

756. Passing the *Ophidian* reptiles (snakes), and the *Saurians*

FIG. 277.

Stomach of Menopoma.

FIG. 278.

Stomach of the Snapping Turtle.

(lizards), we come to the *Chelonian* order (turtles, tortoises); here we find that the nutrimental organs (especially the stomach) have gained a great advance. The injected stomach of the *Snapping*

Turtle (Fig. 278) well illustrates this fact. We here see the gastric cells of the mucous membrane of large size, and the capillaries meandering on their surface in a tortuous direction.

LESSON XLIX.

NUTRITION IN BIRDS.

757. In this class the alimentary apparatus is adapted for the higher forms of animal and vegetable matter, which they obtain in the air, in the waters, or on the earth. The jaws have their margins covered with horny plates, like the Chelonian reptiles, which vary in their forms according to the kind of food they are destined to feed on.

758. The broad, depressed bills of *Ducks*, *Geese*, *Swans*, and many other aquatic birds, with dentated edges and soft, sensitive lips, are well adapted for obtaining worms, and other small objects under water or in mud. The flat, spatulate jaws of the *Spoonbills* are adapted for quick, lateral motion in the water, and for extracting minute animals from the moist banks of lakes and rivers.

759. The sub-maxillary pouch of the *Pelican* serves as a net for seizing fishes; the straight, sharp bills of *Cranes* and *Storks* dart with precision through the water upon their moving prey, and the long, compressed bills of *Cormorants*, *Gulls*, *Albatrosses*, and other predaceous aquatic birds, terminate above in a sharp inverted hook, to seize firmly the smooth, scaly bodies of fishes. The broad bills, with cutting edges, of the Struthious (pertaining to the Ostrich, two-toed) birds, are adapted to prune the leaves and shoots of plants, and the long, narrow bills of *Woodpeckers* to be inserted into small crevices to seize minute insects, and most of the insectivorous birds have a similar structure on a smaller scale.

760. The long, tubular beak of the Humming-bird is suited for insertion into the corollæ of flowers. In the *Grosbeaks* and *Cross-bills*, the *Sparrows* and *Buntings*, and all the granivorous (feeders on grain) order, and in the common poultry, the bills form stronger and shorter cones, broader at the base, to break down and remove the hard coverings of grain. In the climbing *Cockatoos*, *Parrots*, and *Maccaws*, the broad and powerful bills serve as prehensile organs, and to break the hard, shelly coverings of seeds. The bills of *Eagles*,

Vultures, *Hawks* and *Owls*, and other rapacious birds, are strong, short, compressed, arched, curved at the point, dense in their texture, and with sharp, cutting edges, to seize, and tear, and cut the flesh of living prey. In fine, the external forms of the mouth correspond with and indicate the structure of the internal organs of digestion, and afford useful characters for the division of the class. Want of space, however, will not permit more than two illustrations of the digestive organs, and the birds selected for this purpose are the common Fowl and the Crow.

FIG. 279.

Alimentary canal, Fowl.

761. The length of the nutrimental canal differs greatly in the several orders of Birds; it obeys the common law of being shorter in the flesh-consuming tribes, and of greater length in those feeding on a vegetable diet. In nearly all the members of this class, the food is detained in a preliminary sac, formed by the dilatation of some part of the mouth, pharynx, or œsophagus, before it passes into the stomach, and in this receptacle it frequently undergoes a partial state of digestion. In most of the small birds, feeding upon grain, and in the common poultry, a special sac is developed from the œsophagus, called the crop (*b*, Fig. 279). The food is allowed to lie and macerate for some time in a fluid abundantly secreted by a number of follicles situated in the walls of the crop, which prepares it for the more perfect process of digestion, which it will receive in the stomach.

762. From the crop the œsophagus (*a*) continues, exhibiting

another but slight enlargement (*c*) before it enters the stomach; this second sac is called the "proventriculus" (*pro*, before; *ventriculus*, the stomach). This latter organ secretes a gastric fluid proper, which additionally prepares the food for the stomach's action. The gizzard, or true stomach of these birds (*d*) next succeeds, and if its structure be found on investigation to be peculiar, so at least is its function. Examined carefully, it will be found to possess two pairs of muscles; of these, one pair is moderately, while the other is most immoderately, developed; the interior, too, is lined with a hard, callous, non-vascular, perfectly insensible, membrane.

763. The action of these muscles is to press the sides of the stomach (gizzard) firmly together, and produce and sustain a lateral, grinding motion, by which means the hard food may become thoroughly triturated (reduced to a very fine pulp). To assist this most remarkable process, these birds always swallow small particles of flint, for without its agency the probability is that the perfect reduction of the food could not be accomplished. These flinty particles, combined with the constant, firm, lateral motion of the muscles, and aided by the insensible lining membrane of the gizzard, form an excellent apparatus for the purpose required.

764. Those persons who keep Canaries, and other singing birds, instead of sprinkling fine gravel on the bottom of the cage, that the poor birds might help themselves to flint, to assist their digestion, usually give them a piece of Cuttlefish-bone (Carbonate of lime!), which is useless.

765. The consequence is, the poor creatures sicken (of dyspepsia) and die; if any one will make the experiment, and try the effect of some minute particles of silica on their favorite song birds, the extreme greediness with which it will be consumed will speedily assure them of the necessity for its continuance.

766. The liver, of fair dimensions (*e*), discharges its secretion, by its proper duct, into the duodenum; the well-formed gall bladder (*f*), and a pancreas, or sweetbread (*g*), are also met with. The duodenum (*h*) succeeds the stomach, or gizzard; if the latter be found devoid of blood-vessels, the like cannot be said of this commencement of the small intestines, for, on the contrary, its inner surface is densely covered with villi (like the *pile of velvet*, and giving a velvety

FIG. 280.

Villi of the duodenum of a Fowl.

appearance to the intestines), of unusual size, and remarkable for the squareness of their contour (Fig. 280); it will be seen, by reference to the figure, that the villi are intensely vascular. To this succeeds the small intestine (*i*, *i*), the cœcum (*k*), and the large intestine (*m*), terminating in the cloaca (*o*).

Fig. 281.

Gizzard, duodenum, &c., Crow.

In the common Crow, the alimentary canal possesses much general agreement with the like organs in the Fowl; points of difference, however, occur.

A portion of the œsophagus (*a*, Fig. 281), together with the gizzard and commencement of the duodenum, has been accurately copied from a dissection. It will be apparent that the enlargement at the cardiac portion of the œsophagus (*b*) exceeds that of the Fowl.

The pylorus (*d*) marks the point where the duodenum (*c*) commences. The gizzard (*e*), although not very large, possesses muscles of great power. These will be better understood by consulting Fig. 282, in which this organ is seen cut open. The lower part of the œsophagus (*a*) conducts to the cardiac enlargement (*b*). A muscle of the larger pair is cut through at *c*, and a muscle of the smaller pair at *d*. The deep folds and wrinkles of the interior of the stomach (gizzard) are referred to at *e*.

Fig. 282.

Gizzard laid open, Crow.

The intestines exceed in length those of the Fowl, and terminate without the development of a cœcal appendage.

LESSON L.

NUTRITION IN THE MAMMALIA.

767. The digestive organs vary more in this class than in any other of the Vertebrated animals; moreover, they present the highest type of development in the various organs connected with the function of nutrition.

768. The high condition of their organs of sense assist these animals to perceive minuter differences in the chemical and physical properties of their food; while the structure and fixed position of the teeth enable them to comminute their aliment, and mix it sufficiently with the secretion of the salivary glands, for the final purposes of digestion.

769. The *Rodentia* (*gnawing*) present some striking peculiarities in connection with the development of their nutrimental organs. Although possessing but one stomach, it contains, nevertheless, the elements of two very distinct organs. The stomach of the common Rat (Fig. 283) offers a good illustration; the œsophagus (*a*) communicates with nearly the centre of the organ, and can, with the like ease, deposit food on either side. By inflating and drying such an illustration, a line of demarcation will then be visible, clearly dividing the organ into two distinct parts; that towards the pylorus (*b*), on the right side as it lies in situ (*d*), will appear to be *thick*, as if composed (as in truth it is) of the three coats common to such an organ; on the left side (*e*) there is superior transparency, and a number of lines, ridges, or furrows, transverse in their direction; the duodenum commences at *c*. In the figure the organ is reversed, but it is everywhere described correctly.

FIG. 283.

Stomach of the Rat.

770. If, instead of inflating and drying the stomach, it be cut open for examination, the left side (*e*) will be found devoid of mucous membrane, or muscular coat; both of which, together with an external serous coat, are found in connection with the right side (*d*). To render our examination complete, we should try the injecting syringe, to ascertain the vascularity of the organ, and here a very interesting fact is disclosed: the *right side* of the stomach is in-

12

tensely vascular;—the left side consists of a hard, callous, insensible, non-vascular membrane, comparable in every respect to the membrane lining the gizzard of the fowl. An injected preparation of the stomach of the Musk-Rat (so far as it is vascular) is offered in Fig. 284; it is useless to attempt to show the other half, for not one single vessel does it possess. But the mucous membrane of a true digestive cavity is admirably shown in the vascular portion.

FIG. 284.

Mucous membrane of stomach, Musk-Rat.

771. Many of the Rodents (the common Rat, for example) are omnivorous; feeding indiscriminately upon all that comes in their way; at one time eating flesh, at another grain.

772. It has been supposed, therefore, that flesh would be placed in the right side of the stomach, and digested on the principle common to all carnivorous animals; and that, when a material as refractory as wheat was purloined from a farmer's granary, it would be transferred to the left side, and become subject to the same kind of trituration as if found in the gizzard of a fowl.

773. But inasmuch as *all* the gnawing animals (Rodents, including even the Mice) possess the same kind of stomach, and many of them are strictly vegetable feeders (Musk-Rat, and others), this opinion must be given up, and at the present moment we can only confess our ignorance of the intention and special use of this remarkable dual (two) organ.

774. The wants of those animals designed to feed exclusively on grass, are peculiar, and necessitate an arrangement of the nutrimental organs of such a kind, that no parallel can be found in the animal kingdom, except in certain Insects, organized to consume the same material, and there we find a like adaptation of parts. Of all the various forms of food given to animals as their natural pabulum, none is found to contain such a mere atom of nutrient material as grass. Moreover, the nutriment, small as it is, is locked up in a particular manner, so that the means in ordinary use for the resolution of other substances, are altogether inadequate for the dissolution of a substance so refractory and unyielding.

775. In the herbivorous quadrupeds (Cows, Sheep, Deer, &c.) we find four distinct sacs, or stomachs, devoted to the reception, maceration, and digestion of the food (Fig. 285).

776. In a state of nature, the herbivora, naturally timid, and

dreading assaults from their foes, the Feline animals, go to the pastures in flocks, for mutual protection. Here they will be seen busily engaged in cropping the herbage only, and when their hunger is satisfied, they hie away to secure and shady retreats, to digest, at their leisure, the material they have provided for that purpose.

Fig. 285.

Digestive sacs of the ruminant quadruped.

777. In a domesticated state they have no cause for fear, and as soon as they feel satisfied, they throw themselves lazily and listlessly on the grass, to commence the process known as "rumination," or "chewing the cud."

778. While steadily engaged in cropping the grass, the crude food is passed down the œsophagus (*a*) to the *first stomach*, which is by far the largest (*b*).

779. This is called the *ingluvies*, or *paunch*, and is simply a huge collecting bag, analogous to the crop of a bird, or an insect. The food lies macerating in the paunch, in a fluid, apparently of no chemical significance, secreted by the organ.

780. During the period the animal has been collecting grass, some of it has been squeezed out of the over-distended paunch, into the *second stomach*, or *reticulum*, so called from the honeycomb-like structure of its interior. This stomach (*c*) is small, its internal surface consisting only of honeycomb cells; into these the morsels of grass expressed from the paunch go, and by the action of the muscular coat of the stomach, aided by a little water generally found in the cells, the grass becomes converted into a round ball.

781. When all is prepared for rumination, one of these balls is suddenly jerked up the œsophagus into the mouth, and submitted, for the first time, to the action of the grinding teeth.

782. These organs are of peculiar structure, as will be hereafter seen; a most lengthened process of mastication now commences, and contemporaneously the food is thoroughly insalivated from the copious secretion of the salivary glands, which are always well developed in these animals. Thus the vitality of the grass is perfectly destroyed, and it is at last fitted to descend the œsophagus, a second time, with its tissues loosened, and prepared for the ultimate process of resolution by the stomach proper. It descends the œsophagus, but it passes neither into the first nor second stomach, but, by means of two thick muscular folds placed across the opening of communication,

a canal is formed which conducts to the third stomach, the *omasum*, or *many plies* (*d*).

LESSON LI.

NUTRITION IN MAMMALIA, CONTINUED.

783. This stomach is of much greater dimensions than the second, and much longer than wide; its interior consists of a vast number of folds of a membrane, hence the word many plies, or folds, whereof every alternate fold is large and deep, and the intermediate one short and shallow. The food gets impacted closely within these folds, and, from its appearance, no less than the quantity of moisture found always in the membranous folds of this stomach, its function appears to be to press the food, and absorb from it all extraneous moisture. The effect of these folds is like that of a series of damp towels, and it is quite remarkable how compact and comparatively dry the food becomes in the omasum. In due time it passes through an aperture of communication into the *abomasum*, or *reed*, the fourth and last stomach (*e*).

784. Examined by the microscope, this is the only organ possessing a mucous membrane organized to secrete gastric juice and mucus, and digestion of the food in this stomach appears to proceed precisely on the same plan as in those animals possessing only one stomach. These animals, therefore, in common with insects, possess really but one digestive sac, all the others being auxiliary, and endowed with functions extraneous to that of true digestion, but necessary and essential, from the unmanageable nature of their food. The duodenum is seen at *f*.

785. In the Camels and Dromedaries, the second stomach becomes of great importance, as its cells are employed as a reservoir to contain large quantities of water to supply its daily need when traversing the dreary and parched deserts, where no water can be found. The surface of these cells (in them) is covered with a layer of muscular fibres, and the animal possesses the power of opening these apertures, to admit a small supply of water only to escape, and closing them again, as soon as its immediate want is supplied. So great is their thrift and economy in this respect, that Camels have frequently been known to travel for thirty days without water.

786. The length of the intestinal canal is always great in vege-

table feeding animals; thus, in the Sheep, the canal is upwards of thirty times the length of the body, and it is of proportionate dimensions in the Cow, &c.

787. In structure, the intestinal canal presents a villous membrane of great beauty, and the glandular system of the intestines, so well displayed in the Carnivora and in man, is no less displayed in these animals.

788. In the small intestines, especially in the Ileum, patches of glands more than a finger long present themselves; these are the glandulæ aggregatæ, or agmenatæ (aggregated glands) of Peyer. Usually these glands are non-vascular, but, in the figure of them

FIG. 286.

Ileum and Peyer's glands, Calf.

FIG. 287.

Colon, Calf.

presented, drawn from a preparation (Fig. 286), it will be seen that the surface of each gland (*b*, *b*) is covered with a network of capillaries, having wide meshes; the villi (*a*, *a*), in the midst of which the glands are situated, are beautifully seen.

789. In all the higher animals it happens that the large intestine (Colon) reproduces, as it were, the peculiar cellular structure which distinguishes the stomach, and so very like it, that frequently it becomes very difficult, if not impossible, to discriminate between stomach and colon; this is the more surprising when we consider how many yards of a totally different structure intervene between these two organs. A figure of the Colon of a Calf is given (Fig. 287), in which the cellular structure is shown.

790. In the Carnivorous animals the structure of the teeth is essentially different from those of the herbivora, and better adapted as organs of prehension, mastication, and for tearing and dividing their food; but there is yet another organ singularly modified to suit special wants, and this is the Tongue.

791. The tongues of all the higher, and many of the lower vertebrata, possess (usually) three forms of papillæ: the *filiform* (a thread

or filament), *fungiform* (mushroom shaped), and the *circumvallatæ* (surrounded by a ditch). All these forms are found without any addition in the feline animals, but in them the *filiform papillæ* are modified to subserve the purposes of teeth.

792. In a state of nature, these animals are subject to "a feast and a fast," and frequently have to endure long intervals of abstinence from food; whenever it is present, therefore, they make the most of it; feeding to repletion, the first day or two, if the prey be large, till at length the carcass is demolished, and nothing remains but the bones. These are not yet reduced to the condition of a skeleton; the attachments of the several muscles, and their tendinous terminations, yet remain firmly connected to them.

793. Still they are much too short for the teeth to grasp, and the animal must now depend upon the kindly offices of the tongue, or starve.

794. It proceeds, therefore, *to lick the bones*, and the flesh peels off at every effort; this long, soft, flexuous organ can, and does, penetrate all the cavities and sinuosities of a bone, especially at the articulating surfaces; nothing can resist its power; even the periosteum (the membrane that tightly covers a bone) is found to submit, and all that remains, when the process of licking is over, is a white, perfectly clean, well-prepared skeleton.

795. Those persons who have suffered their hands to be licked by an affectionate domestic cat, will have an idea of the potency of this organ; nay, they must be conscious that if they could endure the affectionate demonstration for only a very few minutes, the cuticle would be abraded, and blood would freely flow from the true skin.

LESSON LII.

NUTRITION IN THE MAMMALIA, CONCLUDED.

796. In order to make the foregoing statement fully comprehended, a figure is given of a Cat's tongue (Fig. 288), copied from a preparation. The tongue of a Lion is in every respect precisely similar, but larger. The filiform papillæ (a) are found from the apex, where they are interspersed with the fungiform (b), to about one-third of the length of the tongue, and at this point they increase in size, and

have their external surface covered with a dense horny layer. This increase in size continues to, and beyond the centre, at which point they have assumed very formidable dimensions (*a*). Near the base of the tongue, the circumvallate papillæ (*c*) are found; they are six in number. These are only greatly enlarged fungiform papillæ, and the ditch by which they are surrounded is filled with *mucus-crypts*, or the mucus-follicles of Leiberkuhn, who first described them. They are the external outlets of mucus-tubes, mucus being abundantly poured out to lubricate the upper surface of the tongue.

Fig. 288.

Cat's tongue.

Beyond the Circumvallatæ, are other filiform papillæ, but destitute of a horny covering, their situation being too remote to be effective as teeth; they are covered with mucous crypts, so well formed, that they possess a callous margin. From the peculiar covering of the filiform papillæ in the Feline animals, it is probable that they are not endowed with much sensibility as organs of taste, but that this function is exercised by the fungiform papillæ alone.

797. The stomach is well formed (as regards its ultimate or

Fig. 289.


Stomach of Cat.

Fig. 290.


Ileum of Cat.

microscopical character), as might be expected in a true carnivorous animal, and a figure of the Cat's stomach is given (Fig. 289).

798. Another remarkable modification of structure is met with in the villi of the intestines, which in all these animals are singular-

ly long and narrow; nothing can exceed, however, the beautiful arrangement of their capillary plexuses (Fig. 290). The small intestine of the Cat shows this very nicely, but in the Lion (Fig. 291) it is still better shown, as the capillaries in the Cat are of extreme tenuity; but in the latter the vessels and the villi both attain their maximum development, so far as is consistent with this class.

799. The intestinal glandular system is also well developed in these animals; the form of the glands differs pretty much from those we have already seen: thus, in the aggregated glands of the Lion (Fig. 292), each gland stands in a cup, or surrounded by a ditch, which is filled with mucus-crypts, the gland itself being somewhat conical in form, the top constituting the larger portion.

800. But in addition to the aggregated, animals have, in their

FIG. 291.

Ileum of a Lion.

FIG. 292.

Peyer's glands, Ileum of Lion.

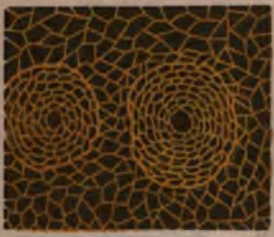
small intestines, glands of the same character and form, dispersed widely, and found singly: these are *the solitary glands.* The large intestine has its glands also, always however of the solitary kind, and being in structure the exact converse of those we have yet examined. The glands hitherto seen were *evolved* (opened, expanded), those to be described are *involute* (to envelop, to cover with surrounding matter); in other words, they are funnel-shaped cavities, excavated as it were out of the mucous membrane. In the first, we saw the outside—in the last, the inside; both these glands are really shaped alike, but they are reversed in their position.

801. Again, reference is made to the large intestine of the Lion for the demonstration (Fig. 293); here the capillary structure of the mucous membrane is everywhere seen; it surrounds the cavities of the solitary glands, and enters them to a certain depth.

To render this more intelligible, a section of the last preparation is figured (Fig. 294). The capillary plexuses of the mucous membrane are seen upon the upper surface, and descending for a space into the cavity of the gland, and finally, its funnel-shaped interior is well shown.

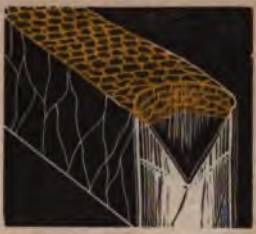
The large intestine (colon) of the Feline animals agrees in general particulars with the characteristics usually exhibited in the animal kingdom, with respect to the great resemblance it uniformly

FIG. 293.



Solitary glands of large intestine, Lion.

FIG. 294.



Section of solitary gland, Lion.

bears to the structure of the stomach. A figure (295) of this part of the intestine of a Cat is given.

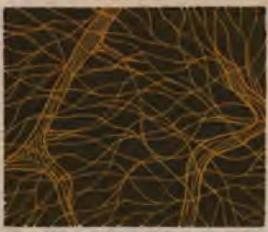
If the papillary surface be carefully dissected from a well injected intestine, the sub-mucous tissue will be found to present a beautiful view of the vessels which supply blood to the villi, and of those which are employed to effect its return—in other words, arteries and veins.

As these vessels end or commence in capillaries, they are neces-

FIG. 295.

Colon of Cat.

FIG. 296.



Vessels of the sub-papillary layer, Lion.

sarily minute; but in the layer immediately beneath, the larger vessels, in connection with this particular plexus, are found.

A figure of this structure, from the small intestine of the Lion, is given (Fig. 296), which shows all that has been described.

802. In the Canine animals (Dogs), many of the tissues differ greatly from those of the Feline; the tongue, for example, is remarkable for its extreme softness and ductility. Possessing villi of the same denomination, in these animals they appear to be endowed with exquisite sensibility, at least the distribution of the gustatory nerves (nerves of taste) would lead to such conclusion.

803. A figure of filiform papillæ of the Dog, minutely injected, is given in Fig. 297, and also of two circumvallate papillæ in Fig. 298; in both instances the terminal nervous loops accompany the capillaries, and necessarily impart great sensibility to these organs. The circumvallatæ are very small in the Dog.

FIG. 297.

Filiform papillæ, Tongue, Dog.

FIG. 298.

Circumvallate papillæ of the Dog.

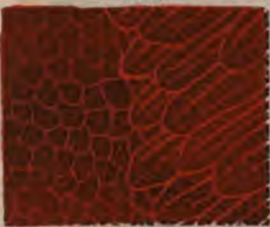
FIG. 299.

Mucous membrane of Stomach, Dog.

804. The structure of the mucous membrane of the stomach of a Dog is highly interesting, as will be seen by reference to the accompanying figure of it (Fig. 299). Here the gastric cavities are beautifully formed, their cell-walls consisting of a single, tortuous capillary blood-vessel, and the deep-seated vessels which surround the mucus-tubes are well shown.

805. The line of demarcation which separates one tissue from another is always remarkably abrupt. Some (theoretical) physiologists hold, that the change of one form of tissue into another is so very gradual as to become quite insensible; an opinion entirely opposed to fact: for example, the structure of the stomach continues half way through the pyloric valve, the other half of it being duodenum, as will be seen in Fig. 300, from the Dog. It is quite true that the stomach exhibits papillæ, in addition to its gastric cells, prior to the commencement of the pyloric valve, and within the stomach—a foreshadowing of the important tissue hereafter to become, not the exception, but the rule; they do not extend, however, to the pylorus, and are more usual in man than in the stomach of domestic animals. So, too, as regards the ilio-cæcal valve, which forms the junction of the ileum with the cæcum and colon; the structure of the small intestine remains intact half through the valve, when the cæcum abruptly joins it. An

FIG. 300.



Junction of stomach and duodenum, Dog.

artery, with its three distinguishing characteristic coats, ends abruptly, suddenly, in a capillary; the structure is altered, and so is the character of the circulation. In like manner, a capillary suddenly terminates, and a vein, with its characteristics of structure and function, commences, and so with other tissues: each maintains its own integrity without compromise, and ends only at the point of junction with another tissue.

806. The duodenum of a dog is a most surprising sight. The great length and breadth of the villi, conjoined with the large distribution of capillaries to each villus, renders the preparation under the microscope a very gorgeous one.

This is represented, as far as art can go, in Fig. 301, but the white lines on a black ground form but a sorry substitute for the rich color of the vermilion which has been injected into the vessels to simulate arterial blood.

FIG. 301.

Villi of the duodenum, Dog.

807. In the Jejunum (empty, and so called because this intestine is always found empty), the form and size of the villi undergo modification in all animals, and this is repeated in the Ileum; examples, however, are not necessary in this connection.

808. In the colon, as shown before, the structure of the stomach is so nearly reproduced that it is extremely difficult to define one tissue from another; in fact, the only rule appears to be the following: generally the gastric cells of the stomach are wider on the surface, and deeper than the cells of the colon, consequently it is easy to penetrate many of the former by the microscope, and see the capillaries on the floor of the cell, around the mucus-tubes. (See Fig. 299.) As there is no such structure in the cells of the colon, the attention of the observer is necessarily restricted to the surface, and here the identity with the stomach appears to be perfect.

FIG. 302.

Colon of the Dog.

The colon of the Dog is shown in Fig. 302, and fully justifies all that has been said of it.

Enough has now been written, and examples sufficient have been produced, to show the principles of nutrition, as displayed in the animal kingdom; those subjects which

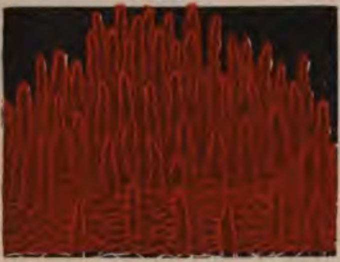
have hitherto been lightly dealt with, notwithstanding their important influence on the great question under discussion, have been reserved designedly until the salient points in regard to the ultimate structure of the (apparently) most important organs had been disposed of; and because it was deemed more advisable to take such subjects specially, in connection with the nutrition of man. These are, the structure of the teeth, the structure, but more especially the function of the salivary glands, and the properties of the gastric juice and mucus.

LESSON LIII.

THE STRUCTURE OF THE TEETH.

809. The teeth claim priority, and, reversing the order of arrangement hitherto pursued, in which the lower animals have served as the basis for the consideration of more complicated structures, devoted to the performance of a kindred function in the higher forms of animal life, it is intended to begin these inquiries with man, and gradually descend in the scale of being.

FIG. 303.



Mucous membrane of the gum, human.

810. The mucous membrane of the gums, which lies at the bases of the teeth, is peculiar, and requires description.

If a well injected preparation be made, the mucous membrane of the gum will be found covered with papillæ. These (in the adult) are somewhat long, and consist of a single looped capillary, which, through the tension of the injection, becomes more or less twisted (Fig. 303). Their number is very considerable, presenting, literally, a forest of them. The papillæ of the lips present a gorgeous sight, when well injected; the loops, as in the former case, twisting with the pressure of the injection.

THE TEETH.

811. These organs, together with the bones, to which they are closely allied, form the sclerogenous (hard) tissues of animals.

812. Human teeth, and the teeth of the higher mammalia, con-

sist of three distinct tissues; the dentine, or ivory, which forms the greater part of the tooth, and contributes to its form; the enamel, which covers and defends the outer, exposed surface of the tooth; and lastly the crusta petrosa, or cementum, which forms the external covering of the fang. The interior of a tooth contains a cavity of variable size, called the pulp cavity, in which, in a healthy tooth, the vascular pulp, with its plexus of nerves, lies.

813. As the enamel first meets our gaze, it shall have priority of description. This tissue, in the grinding teeth, is thickest on the masticating surface. A delicate membrane, discovered by Nasmyth, and known as "Nasmyth's membrane," covers the enamel, and is so closely united with it, that they can only be separated by the employment of hydrochloric (formerly muriatic) acid.

814. The enamel is so much more brittle, and harder than the other tissues of the teeth, that a knife scarcely marks it, and it readily yields sparks when struck against steel.

815. This tissue presents a fibrous structure, due to its composition, which consists entirely of the prisms or fibres of the enamel. These are long, solid prisms, irregular in shape, but usually hexagonal, or pentagonal, generally occupying the whole substance of the enamel, resting by one extremity on the dentine (ivory), and by the other on Nasmyth's membrane.

816. In adult teeth it is easy to detect these elements in longitudinal or transverse sections, but it is difficult to separate them for any great length; it is easier of accomplishment in young and developing teeth, where the enamel is so much softer that it may be cut with a knife. The action of diluted hydrochloric acid is necessary to effect the separation of the prisms, and, if not too long continued, delicate transverse striæ may be detected on their surface.

817. The prisms of the enamel are very firmly united, but what constitutes the bond of union, has not yet been satisfactorily demonstrated; delicate tubes have been clearly established in connection with this tissue in young animals, and although difficult of detection in adults, the probability is that they are present, although it may be in a calcified condition.

818. In making a section of a tooth, to show the facets of the prisms of enamel, great care should be taken not to injure the external surface, but grind from behind until sufficiently thin.

819. A figure of such a section, from a human tooth so prepared,

is given (Fig. 304); here the facets are four, five, or six-sided, with a nucleated spot apparent in each of them.

820. The isolated prisms are also given in Fig. 305; the transverse lines serve to give them a jointed appearance; the sides, too, are remarkable for their irregularity.

821. If the mode by which the several prisms are connected to

FIG. 304.

Facets of the enamel, human.

FIG. 305.

Prisms of enamel, human.

each other, and enabled to form a solid tissue, be obscure, there can be no doubt of the manner in which the dentine becomes firmly connected to the enamel. The dentinal tubuli, as they approach the enamel, divide and form Y-like terminations, which (in the molar teeth) penetrate the enamel, and thus form a bond of union; but in human canine teeth, a much more efficient plan is in operation, as shown in Fig. 306, which represents the junction of the dentine and enamel in a human canine tooth. Tubes of the dentine (*a*, *a*) having entered the enamel, become tortuous, and greatly increase in size, especially as they approach their terminations; they form a series of wedges, or dowells, which renders the contact so firm that no earthly power can separate tissues so joined. Strike a tooth on an anvil with a hammer, the blow will break the tooth in all manner of directions, but no mechanical skill can separate the

FIG. 306.

Junction of dentine and enamel, human Canine Tooth.

enamel of such a tooth from the dentine at its point of junction. This plan of attachment appears only to be used for teeth like the canines, that are brought violently into contact with resisting substances; other teeth, the molars for example, having a steady, uniform action to perform, do not require such extraordinary care, neither is it bestowed upon them. To show the mode of connection with the enamel of a molar tooth, see Fig. 307.

The dentinal tubuli are seen at *a*, their terminations dividing into two branches (*b*) prior to reaching the enamel (*c*), which forms the mode of connection of the two tissues.

822. The junction of dentine with the crusta petrosa, or cementum, is also by the insertion, or interlacement, of the terminal bifid dentinal tubuli with the cementum; and as there is no strain or violence to any part of the fang, this mode of connection appears to be

FIG. 307.

Connection of Ivory and Enamel, Molar Tooth.

FIG. 308.

Junction of Ivory and Crusta Petrosa.

all that is necessary. It is interesting to observe that whether the dentine has to be connected to the enamel or to the crusta petrosa, that its own tubuli are employed as the bond of union.

The fang of a tooth, from its position in the bony socket of the jaw (alveolus), is greatly protected from acts of violence; whilst the same appliances are in use to join the crusta petrosa to the dentine, the branches of the tubes of ivory are so minute as to be scarcely distinguishable. For the most part, the junction of these tissues rather indicates a dark line, of no great depth, in which the divided tubes are scarcely apparent. This will be understood by consulting Fig. 308, which shows the crusta petrosa (*a*), dentinal tubuli (*b*), and the junction of the two (*c*); but such is the extreme minuteness and shortness of the divided dentinal tubes in connection with this tissue, that they are scarcely discernible.

LESSON LIV.

THE STRUCTURE OF THE TEETH, CONTINUED.

823. Examined in transverse section, the prisms of enamel are well seen throughout their course; they are distinguished by a series of transverse lines at regular intervals (Fig. 309), which appear to divide the tissue into small squares, or dice. When the prisms are isolated (as we have seen), the same appearance appears to be caused by the transverse lines on their surface. On the other hand, it has been supposed, and with probability, that these transverse lines indicate the several stages of growth of the tissue, and that, although division of it in the direction indicated by the lines is impossible, the evidence of demarcation defining its original stages of growth, is rendered permanent. If the surface of enamel be destroyed, the facets of the prisms are lost, as already indicated.

FIG. 309.

Transverse section of Enamel, human.

824. The dentine or ivory of a recent tooth is of a yellowish-white color, and transparent; in a dried tooth, air enters the tubuli, and imparts to it a silky or satiny appearance. The dentine forms the walls of a case, in which the pulp is received, so that the tubes of this tissue have uniform contact with the vessels of the pulp. At the lower part of the fang of a tooth there is a small aperture, through which the vessels pass to supply the pulp, and through which also the nerve, to be divided into a delicate looped plexus, is transmitted.

825. The dentine consists of minute canals, or tubuli, which commence by open mouths on the inner wall of the pulp cavity, and extend through the whole substance of the dentine to the cement and enamel. Each tube has a wall, less than its own diameter in substance, which can easily be seen in transverse sections; in longitudinal sections it is almost invisible. In life these canals contain a clear fluid, but in a dead tooth the tubuli become filled with air; and as air in small cavities always appears black under the microscope, these tubuli appear as so many small, delicate black lines; but if the tooth be prepared in Canada balsam, the air is driven out of the tubuli by the heat employed in making the preparation, and the turpentine of the balsam enters them; in this case they appear as delicate tubes.

826. The direction of the tubuli in the dentine is rarely straight,

but wavy; they also present numerous ramifications and anastomoses; towards the crown of a tooth they usually form an elegant plume, which presents a fine object under the microscope. Each tube generally describes two or three large, besides a great number of small curvatures, which occasionally have the appearance of zigzags, or spiral windings.

FIG. 310.

Longitudinal section of Canine tooth, Human.

827. To show the connection of the three tissues of the teeth, and their relation to each other, a figure is given of a longitudinal section of a human canine tooth (Fig. 310). The enamel is marked *a*, the dentinal tubuli, *b*, *b*, the pulp cavity, *c*, the crusta petrosa, or cementum, *d*, and thin plates of dentine, *e*.

828. The cementum is a layer of true bone, which covers the lower part of the teeth, and in the many fanged teeth, not unfrequently cements them all together. The cementum commences above, at the point where the enamel ceases, so that the dentine in a healthy tooth is never left exposed to the atmosphere. It begins as a very thin layer, gradually increasing in substance as it descends, and attains its greatest dimensions at the lower part of the fang.

829. As bone, it may readily be imagined that it is the least hard of the dental tissues. Like bone, the cementum contains bone cells, with their canaliculi, together with Haversian canals and vessels. The bone cells are conspicuous for the great variety which they present in number, form, and size, and for the unusual number and length of their canaliculi (little tubes).

830. The canaliculi often resemble feathers and brushes, and unless the lacunæ (bone cells) are isolated, connect them with each other, and anastomose with the ends of the dentinal canals or tubes. At the point of junction with the enamel, bone cells are invariably absent; they first make their appearance about the middle of the fang, but scattered and solitary. Towards the extremity of the fang their number increases, and they frequently take on a very regular arrangement.

831. In old teeth it very commonly happens that the pulp becomes obliterated, and the pulp cavity filled with cementum; and in these cases the Haversian canals, lacunæ, and their canali-

culi, are more than usually distinct.

832. In the figure several very thin transverse sections of the dentine appear, attached to the sides of the pulp cavity (*e*); these exhibit the tubular character of the canals very satisfactorily.

FIG. 311.

Transverse section of Dentinal tubes.

FIG. 312.

A more crowded view.

833. Special reference is made to these thin sections of the tubes as they are ordinarily seen, in another figure (Fig. 311) much more highly magnified, indicating the tubes, and a more crowded condition of them in Fig. 312.

LESSON LV.

THE STRUCTURE OF THE TEETH, CONTINUED.

834. In the teeth of the Dog the same tissues, arranged on the same plan, are found, and present in the molar teeth a very interesting appearance (Fig. 313). The enamel (*a*) is always distinguished by its apparent density, as compared with the other tissues; towards the edges of the upper portion of the figure (*b*), the terminal line of the enamel, and the commencement of the crusta petrosa, is shown. From this point it (crusta petrosa) can be traced descending the fangs, right and left, to their termination, then ascending, and finally forming a junction at the centre. On the inner surface of the enamel, and crusta petrosa, the dentine is seen (*c*), and within this tissue the large, well-formed pulp cavity (*d*). At the bend, which connects the two fangs, the dentinal tubuli assume a curious and very beautiful arrangement.

FIG. 313.

Molar Tooth, Dog.

835. The molar tooth of a Cat displays the same arrangement of the like tissues, and the external form of the tooth bears great resemblance to the molar of the Dog (Fig. 314); *a*, the enamel; *b*, crusta petrosa; *c*, dentine; and *d*, pulp cavity.

836. A transverse section of the canine tooth of a Horse presents the same tissues under a different aspect. The section has been made so near to the crown of the tooth, that the enamel forms a ring nearly surrounding the dentine (Fig. 315), with the apex of

FIG. 314.

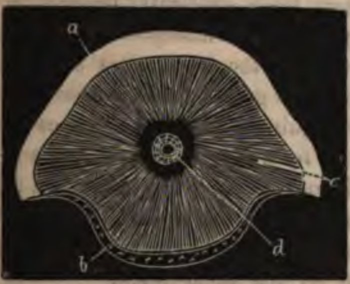
Molar Tooth, Cat.

FIG. 315.

Canine Tooth, Horse, transverse.

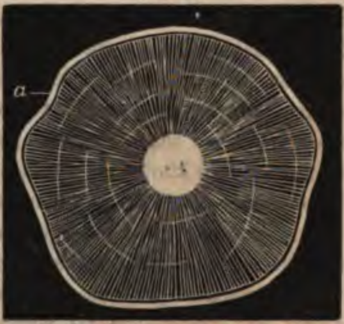
the pulp cavity in the centre. Another section of the same tooth (Fig. 316), made below the former, shows the enamel (*a*) round only one half of the section, the other half being the crusta petrosa (*b*). Between these tissues is the dentine (*c*), and in the centre the pulp cavity (*d*). A third section (Fig. 317), made still lower than the second section, from the same tooth, shows an entire absence of

FIG. 316.



Canine Tooth, transverse, Horse.

FIG. 317.



Canine Tooth, transverse, Horse.

enamel, and the crusta petrosa (*a*) surrounds the section. The dentine, in all these sections, is very nearly the same; the pulp cavity grows gradually larger from its apex to the base, but the most satisfactory part of the demonstration is the number and density of the bone cells, as seen in the last figure, but which is not sufficiently magnified to be apparent in the representation of it.

837. In a tusk of the Hog, as seen in longitudinal section (Fig. 318), the enamel covers the outer surface—that portion which comes in contact with resisting substances, and within it the ivory; the pulp cavity is seen at the lower part.

838. This is probably still better seen in a transverse section of the same tooth (Fig. 319); in this view, the tooth appears to be triangular in form. The large pulp cavity occupies the centre, which

FIG. 318.

Longitudinal section, tusk of Hog.

FIG. 319.

Transverse section, Hog's tusk.

is succeeded by the tubes of the ivory; the enamel entirely surrounds the section.

839. It is reserved for the Herbivorous quadruped to show the most interesting and beautiful forms of teeth known to us among the higher animals. The same three tissues are present here, but arranged in a different manner to meet a special want.

840. These animals having uniformly to masticate grass, either in a dried or green state, have their teeth constantly brought in contact with large quantities of pure silica, incorporated in the cuticle of the grass. If the surface of the teeth were smooth, they would be inadequate to perform the grinding motion assigned to them. We know that the miller requires to have the surface of his mill-stones hacked into cavities to form a grinding surface, and this is precisely the want of the herbivorous quadruped in relation to the surface of its teeth—they must not be flat, but hollowed out into unequal cavities. To meet this imperative want, the tissues—enamel, ivory, and bone—are all arranged on the same plane.

841. Examine the crown of the molar (grinding) tooth of a Cow or a Sheep; its surface will present a series of ridges standing up above the other tissues; next to these are inclined planes of a different tissue, descending from the ridges to large, hollow, unsightly cavities lying at their base—evidently another tissue.

842. Now it must happen that if flint be brought constantly in

contact with enamel, ivory, and bone, lying beside each other, they will wear unequally; the softest (the bone) will cut the fastest, and form the deep hollows described; the next in hardness, the ivory, will wear less than the bone, but more than the enamel; and lastly, the enamel, wearing but little, will form the high ridges described.

843. But this is not all: to render the inequalities certain and constant, there are three systems of enamel in the grinding teeth of the upper jaw of the Cow (*a*, *a*, *a*, Fig. 320), and only two in those of the lower jaw, so that enamel never opposes enamel; by all these contrivances the teeth must necessarily wear unequally, and always present a rough, uneven, grinding surface to the food.

FIG. 320.

Molar of Cow.

844. To show the arrangement of the enamel of a molar of the upper jaw, a figure (320) is given, but slightly magnified. Crusta petrosa (*b*) is found surrounding the tooth; within this a layer of enamel (*a*), which passes irregularly round the outer surface; next to this is ivory, to which succeeds crusta petrosa, on the other side of which ivory again appears, to be bounded by the enamel. Take a given portion of a tooth, and the arrangement of

FIG. 321.

Portion of Molar tooth, Sheep.
a, *a*, Enamel; *b*, *b*, Dentine; *c*, Cementum.

the tissues will be invariably as follows: crusta petrosa in the centre, bounded on each side by ivory, which always adjoins enamel; crusta petrosa and enamel never come together (except on the outer surface); they are always separated by the ivory.

845. These facts are well illustrated by a figure of the grinder of a Sheep (Fig. 321); here the enamel (*a*, *a*) is constantly seen in connection with the ivory (*b*, *b*), and inside of this the crusta petrosa (*c*). The elegant wavy form of the dentinal tubuli renders this a very charming object for the microscope. The crusta petrosa (more properly called cementum in these teeth, as it performs the office of a cement to the other tissues) forms, in many instances, little more than a line in the centre of the ivory, yet quite sufficient for its softness to be felt, and the required hollow to be formed.

LESSON LVI.

THE STRUCTURE OF THE TEETH, CONTINUED.

846. In the Rodentia, the form of the teeth is very interesting: the enamel in the large, curved incisors, is always found upon the opposing surface (front) alone. These teeth, in every member of the class, are constantly being pushed, as it were, from behind, forwards; in other words, continually growing; and to gnaw, from which they acquire their name, is in them an imperative necessity, to keep these teeth in check, and reduce them within usable limits. Were Rats, Mice, Rabbits, and their kindred, not to keep their ever-growing teeth well cut down, by gnawing hard substances, by which the teeth wear considerably, they would soon be unable to use them on legitimate food, and die of starvation.

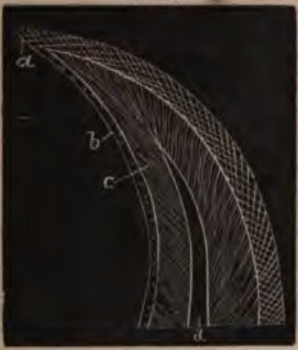
847. If a Rat, or Rabbit, chance to break one incisor tooth, the opposite tooth fails to oppose it; the consequence is, it continues to grow, and forms a perfect ring. The broken tooth also grows, and having attained its original length, and finding no opposition, also forms a ring.

848. To obtain such illustrations for Museum purposes, to show the ever-growing nature of such teeth, one of them has frequently been designedly cut with a fine saw, or wire-nippers, to procure specimens of the curled, or even double-curled teeth; such examples are common in European Museums.

849. A figure (322) of a longitudinal section of the incisor of a Rabbit is given. The enamel (*a*) forms a chisel-shaped cutting instrument at the apex of the tooth; within the point, the crusta petrosa (*b*) forms a very delicate line, which is continued along the inner surface of the tooth; within this tissue, and the enamel, is the dentine (*c*), and in the centre of it, the pulp cavity (*d*).

850. A transverse section of such a tooth (Fig. 323) is very in-

FIG. 322.



Longitudinal section, Incisor, Rabbit.

FIG. 323.

Transverse section, Incisor, Rabbit.

structive; it is somewhat triangular in shape, the front being particularly flat, while the sides recede, and are rounded at the back. The enamel (*a*) occupies the entire front, and for its security embraces the corners, and is gradually lost at the sides; here the crusta petrosa (*b*) begins, and completes the outer wall of the tooth. As in the former illustrations, within these tissues is the dentine (*c*), and in the centre the pulp cavity (*d*).

851. As far as the alternation of tissues is concerned, the molar teeth of the Rodents are formed on the same plan as those of the herbivorous quadruped, the arrangement being, however, somewhat different.

852. A figure of a Rabbit's molar tooth is given in Fig. 324. In preparing these teeth, they almost invariably break into

FIG. 324.

Transverse section of Molar tooth, Rabbit.

four pieces, in consequence of the brittleness of the crusta petrosa,

and such an accident befell this illustration, but which was subsequently repaired. Here the enamel forms partly the outside of the tooth, but a long, tortuous, zigzag portion also runs through the centre (*a*, *a*). The arrangement of the enamel naturally divides the tooth into four portions; within each system of enamel is the dentine (*b*, *b*), with pulp cavities (*c*, *c*) in the centre. In addition, however, is a layer of crusta petrosa (*d*, *d*), which forms the bond of union, or cement, by which the four distinct portions of the tooth are united into one.

FIG. 325.

Transverse section molar, Musk-rat.

853. By far the most curious arrangement is the molar tooth of the Musk-rat; the tooth is long, and formed of a reduplication of parts, with the exception that the enamel is continuous from one end of the tooth to the other, bounding the outer surface, and penetrating the various sinuosities. Everywhere within the enamel is the dentine, and, as in other Rodents, the crusta petrosa lies in the centre of the ivory. Cavities formed by the curious direction taken by the enamel, are filled up with crusta petrosa, for the double purpose of cementing this compound tooth firmly together, and for preserving and forming the outlines. A figure of this tooth is given (Fig. 325); the enamel (*a*, *a*) is seen everywhere surrounding the dentine (*b*), in the centre of which is the crusta petrosa (*c*, *c*), which, filling up the external cavities, is seen at *d*, *d*. If the section be made low enough from the surface, the pulp cavities appear.

LESSON LVII.

THE STRUCTURE OF THE TEETH, CONCLUDED.

854. The teeth, hitherto examined, have presented all the tissues characteristic of these organs in the higher animals, subject to a varied disposition of the order of arrangement. Teeth are liable to degeneration; to a loss of tissue, and to a much altered form of the tissue that remains. Of all these structures enamel is found to be the least constant, and, when absent, its place is supplied by a dentine (ivory) of superior hardness.

855. In the class of Reptiles, the Ophidians (Serpents) are entirely destitute of enamel, and the same remark applies to nearly the entire class of Fishes. In the latter, the dentine assumes new characters; in some Fishes the dentinal tubuli have their origin from *vascular canals*, hence such a tissue is called *vaso-dentine;* and in other fishes the medullary canals are wavy, irregular, and prone to anastomose (join), and is usually covered by a hard dentine; this is called *osteo-dentine.*

856. The teeth of the *Pristis* (Saw-fish), and the *Myliobatis* (a Ray), well display the vaso-dentinal structure, and as such have been selected for illustration.

857. In the Pristis the vascular canals are large, and remarkable for their parallelism; the tubes that are given off from the centre of the tooth, are large in size, and few in number, but those canals which approximate to the sides, give off a dense plexus of fine tubuli,

FIG. 326.

Longitudinal section of tooth, Pristis.

FIG. 327.

Longitudinal section of tooth, Myliobatis.

distributed to the sides and crown of the tooth, and forming the vaso-dentine. This is shown in Fig. 326; the vascular canals (*a*) are seen in the centre, giving off (comparatively) but few tubes. The lateral tubes (*b*) distribute the great plexuses of fine dentinal tubes to the crown and sides; there is no pulp cavity in this tooth.

858. The vascular canals of vaso-dentine can only be well seen in longitudinal sections; for this purpose such a section is given of the tooth of Myliobatis (Fig. 327). Here the vascular canals (*a, a*) are of great size, and, as is usual in this form of tissue, parallel to each other; the dentinal tubuli (*b, b*) are given off in remarkably rich clusters of beautiful ramose tubuli, presenting, under the microscope, a very fine appearance.

859. But the extent of the ramified tubuli must be sought for in a transverse section, a figure of which is given (Fig. 328); in the centre is seen the section of the vascular canals, and the tubuli coming off in profuse plexuses; the tissue which separates the vascular canals and dentinal tubuli, is a thin layer of cementum.

860. A fossil Shark's tooth (Fig. 329) shows the structure of osteo-dentine very satisfactorily, and, to add to the beauty of the

FIG. 328.

Transverse section of tooth of Myliobatis.

FIG. 329.

Longitudinal section of tooth of Shark, Fossil.

preparation, as seen by the microscope, the blood contained in the canals retaining its original color, is also fossilized!

861. Here the canals (*a*) are seen to be wavy, and anastomosing very freely; the chief distribution of the dentinal tubuli is to the sides and crown (*b*), as in the Pristis and Myliobatis.

Another fine example of osteo-dentine is met with in the teeth of the *Maskanongé*, called generally *Muscalonge.* It is a transverse section (Fig. 330), and shows the amastomosing character of the vascular canals very satisfactorily. Near the outer margin of the tooth a canal appears to run round it, from whence the great distribution of osteo-dentine comes off. In the central portion of the section these tubuli are seen anasto-

FIG. 330.

Transverse section of tooth, Muscalonge.

mosing very freely, and contribute to give a fine appearance to the section. The distinction, then, in the tissues of the teeth of fishes is, that in vaso-dentine the vascular tubes are parallel, whereas, in osteo-dentine, they anastomose.

LESSON LVIII.

THE SALIVARY GLANDS.

862. In the human subject, as in all the higher mammalia, there are three pairs of salivary glands; these are the *parotid*, *submaxillary*, and *sublingual* glands.

863. The parotid gland (in man) is the largest of the three pairs, and, situate immediately in front of the external ear, extends superficially for a short distance over the masseter muscle, and behind the ramus of the lower jaw.

864. The submaxillary gland is situated in the posterior angle of the submaxillary triangle of the neck.

865. The sublingual is an elongated and flattened gland, situated beneath the mucous membrane of the floor of the mouth, on each side of the frenum (bridle) of the tongue.

866. In structure they are conglomerate glands, consisting of lobes which are made up of angular lobules, and these of smaller lobules.

867. The smallest lobule is apparently made up of granules, which are minute cœcal pouches, formed by the dilatation of the extreme ramifications of the ducts.

868. These minute ducts unite to form lobular ducts, and the lobular ducts constitute, by their union, a single excretory duct.

869. The above description of these glands applies very generally to the animals in which they are found.

870. It is not a little remarkable that these three pairs of salivary glands are all found in the class of Reptiles, but never in the same individual; one animal possesses the parotid; another, the submaxillary; while a third has only the sublingual.

871. Food received into the mouth is given at once to the grinding teeth, for the double purpose of being thoroughly comminuted and insalivated. One pair of the salivary glands (parotid) has its evacuating duct on the inside of the cheek, opposite to the second molar tooth of the upper jaw, and the action of the jaws, in the act of mastication, not only compels the descent of the saliva in copious streams from these, but simultaneously from the other glands.

872. The salivary glands, and their secretion, appear to be so much alike, that it has been difficult to say whether they all secrete a fluid possessing the same chemical properties or not.

873. But reasoning from analogy of the effects produced by animals possessing some of these glands, to the exclusion of the rest, one would incline to the belief that each pair of glands possesses different chemical properties, or, perhaps, that two pairs of them possess properties distinct from the third, and that the combination of the whole is necessary to the production of the required effect.

874. Mastication of the food, the first act in the process of digestion, is, at the same time, the most important one. If it be performed in a hasty, slovenly manner, dyspepsia is the unfailing result; those persons who have once accustomed themselves to consume their food, dispensing with this preliminary process, never can recover the lost art, and sink into an early grave, the victims of suicide.

875. The saliva appears to possess *three* most important properties: firstly, it destroys vitality in all animal and vegetable matter; secondly, it loosens the tissues, thereby preparing them to receive the saliva itself, and ultimately to admit the gastric juice; and thirdly, it mechanically softens and dilutes hard or dry food.

876. When a Cow fills her paunch with grass, she places there a large amount of living vegetable material; lying in that organ, or transferring it to the second stomach, no way affects its vitality, but when thrown back into the mouth, and it comes in contact with the saliva, then it instantly dies, and becomes materially altered in appearance.

877. Examine the contents of the first three stomachs of a Cow, or a Sheep; in the two first the food is evidently living grass, but in the third it has the appearance of a thoroughly well-boiled vegetable—more nearly allied in color and appearance to spinach, and, as yet, it has only come in contact with the saliva, which must be held responsible for its changed condition.

878. Arrest a caterpillar in the act of eating the leaf of a cabbage; kill it instantly, open its crop, and examine the leaf you saw it consume but a minute before: it will have lost its bright green color, and be reduced, in every respect, to the appearance of the grass in the third stomach of the Cow. As it cannot have come in contact with any other material than the salivary secretion, it is surely justifiable to attribute its altered appearance to the action of that fluid.

879. When man eats raw, ripe fruits, he eats living vegetables,

and if he put them into his stomach in that state, there they will remain, for no stomach has the power to destroy the vitality of any thing, as, if it had, assuredly it would destroy and digest itself, a contingency that always happens in death. Nothing is more common, at post-mortem examinations, than to find that a portion of the stomach has actually thus acted upon itself!

LESSON LIX.

THE SALIVARY GLANDS, CONCLUDED.

880. To show the universality of this particular chemical property of destroying life, let us see what takes place amongst the lower animals. Bulk for bulk, weight for weight, can any thing exceed the pain of a Mosquito bite, to say nothing of the long-continued after consequences?

881. What gives rise to this extreme suffering? Surely it cannot be the insertion of its tubular sheath and tiny jaws, because if the flesh were stabbed at the same time with a dozen large stocking needles, the pain would not be nearly so great, and the wound would sooner heal. When a spider bites a fly, why does the insect die instantly, and its body swell up prodigiously?

882. If a rattlesnake, or other, so called, *poisonous serpent*, bite a man, why is the wound almost universally fatal?

883. If a Dog, not rabid, bite a man, or if a Cow, Horse, Hog, Raccoon, Fox (and many other animals), do the same thing, or if *one man bite another*, why, in any, or all these circumstances, should the bitten person be liable to Hydrophobia?

884. To these questions, which might be greatly extended, there is but one answer, namely, that the person bitten has been in every instance inoculated with the saliva of the other animal, and that one of its chief properties is *to destroy life*.

885. To them, and to us, it is a natural secretion, and so harmless is it, under some circumstances, that a man may drink any quantity of the poison (saliva) *of a Rattlesnake*, and it will have none other effect than to help him to digest his food! But if inoculated into the circulation of the blood, it becomes a virulent, a fatal poison.

886. Who can doubt that, if a Mosquito were as large as a good

sized dog, its saliva would be as immediately and certainly fatal as the bite of a rattlesnake?

887. The pain that we share with domestic and other animals, from the bite of parasitic insects, is solely due to this cause—inoculation by their saliva.

888. The division of the salivary glands amongst the reptiles would appear to throw some light on the function of each, or certainly some of them; thus: the *poisonous* reptiles possess only *parotid glands*, the secretion of which descends by the channels of the fangs of the upper jaw (Fig. 331, *a*); the use they make of them would seem to establish the function and properties of these particular glands.

FIG. 331.

Fang of Serpent's tooth.

889. The Boa Constrictor (*Python tigris*) has no parotid glands, neither can he destroy his prey by a bite, but he entwines his body around his victim, and kills him, as a bear would, by an embrace. But what is now to be done? he has no grinding teeth to enable him to insalivate the food and loosen the tissues, by partially decomposing the body of the goat he has killed, and so prepare it for the action of his stomach; in other words, how can he perform the important function of insalivating it?

890. He does it in this way: *he licks it all over*, and wherever the tongue, covered with saliva, touches it, the flesh becomes almost rotten under its influence.

891. Now, as it is well known that persons have been bitten by a rabid dog and escaped hydrophobia, whilst other persons have been bitten by sound and healthy dogs and yet this fearful disease has supervened, how is this to be explained, unless we admit the differing chemical property of the salivary glands respectively?

892. If the teachings of the rattlesnake and the boa constrictor have any practical value, it would appear that the parotid glands *alone possess the power of destroying life*, and that the secretion of the other glands can only be employed upon already dead matter, to effect its speedy decomposition.

893. If this theory be true, it is very easy to explain the bites and their consequences of the two dogs: in the case of the *rabid dog* whose bite proved innocent, the saliva of inoculation may have come only *from the submaxillary* and *sublingual glands*, and consequently it was harmless; whereas, in the case of the *sound dog*, the saliva came from the *parotid glands*, and was therefore fatal.

894. This view is sustained by the following considerations: the

ducts of the parotid glands are situated, as we have seen, in immediate proximity to the molar teeth, and the secretion is only evolved by their action; the probability is that the incisor teeth, used in biting, and the interior of the mouth, are usually lubricated by the secretion of one or both of the other pairs of glands, whilst the parotid glands are reserved for mastication alone.

895. Whatever light chemistry may throw upon this really important question, remains to be seen, but Comparative Anatomy, the only sure guide in the settlement of abstruse and difficult subjects of this kind, would appear to settle it conclusively, that the secretion of *the parotid glands* affects solely the vitality of all tissues presented to their action; and the secretion of *the other glands* has the power of rapidly decomposing or disintegrating tissues already dead.

896. The third function of the saliva is no less important, namely, to dilute or moisten dry food, and is common to all these glands.

The blood of man and animals is too rich and thick to be consumed in its natural state by parasitic insects; and the motive they have for pouring their secretion liberally into the wound they have made, is twofold,—one to destroy the vitality of the blood, a function their stomach cannot perform, and the other to dilute it, to make it thin enough to be pumped up with ease.

897. In insects, the anatomical position of their salivary glands does not appear to warrant the opinion that they, at least, possess parotid glands; but the life-destroying character of the salivary secretion in all the predaceous, carnivorous, and parasitic tribes, in addition to the same exhibition in all those insects feeding upon living vegetable matter, too clearly points to the function and character of the parotid secretion, notwithstanding the situation of their glands.

898. And why should it be necessary for such insects to have two, and frequently three pairs of such glands, if they all possessed the same capabilities? From this circumstance alone, it would appear that the function is divided; that one pair of these glands has the power of destroying life, and the other pair (or pairs) of decomposing organic matter already dead—both these processes being essential to the ultimate digestion of the food.

899. In the *Nepa* (water Scorpion), there are three pairs of salivary glands—three of them lying on the right and three on the left side of the body. One pair of these glands possesses a distinct outlet, and from the effects it produces by inoculation, entomologists have long ago concluded that these especial glands secrete a poisonous

fluid. Is it not much more probable that they are, in function, parotid glands?

900. To show the difficulties that surround this question, it may be well to remark, that in the Calf, when cooked, all these glands taste precisely like the (so-called) sweetbread, and have the same general appearance.

901. The organ called by butchers the "throat-sweetbread," is, in reality, the submaxillary gland; and the "heart-sweetbread" is the Thymus gland, which is always of great size in young animals.

902. The true sweetbread, or pancreas, is never eaten.

LESSON LX.

THE PROPERTIES OF THE GASTRIC JUICE AND MUCUS.

903. If we eat a dry cracker, we cannot swallow it until it be moistened with the saliva; and the same thing takes place with Cows and Sheep, when they are fed upon dry hay.

904. When food that has been properly insalivated, reaches the stomach, it is destined to come in contact with two other elements, both of which, so far as experiments on artifical digestion have extended, are imperatively necessary for its final resolution into *chyme*. These are, the weak acid, known as *gastric juice*, and *mucus;* and without the combination of the two, in their full integrity, there can be no healthy digestion.

905. From the chemical composition of one of these agents (the gastric juice), it must be evident that those persons who habitually drink much water, must necessarily impair the function of the stomach, as they thereby dilute an already weak acid, until it be powerless; in fact there can be no doubt that the practice of water-drinking to excess is as much a vice as the too frequent indulgence in strong potations, and leads to precisely the same consequences—death.

906. Moreover, water taken in large quantities with a full meal, has another very bad effect: when there is food in the stomach to digest, the capillaries, previously nearly empty, are turgid with blood, which has been withdrawn from the surface of the body and the limbs, to meet an immediate, special want; cold water thrown upon this ex-

cited capillary surface, at once represses this circulation, and drives it back to its former channels. The blood has been summoned to the stomach, at the time it is specially needed, to supply the necessary pabulum for the secretion of mucus and gastric juice, neither of which is kept "on service." Once driven back, what is to become of the food, how is it to be digested, when the material for preparing the solvents for it has been sent away?

907. Water containing much lime in solution is altogether unfit to drink, because dangerous. This earth is eliminated by the kidneys, and passed in the solid form to the bladder, where it concretes, and forms calculi, which can only be removed by the most painful and dangerous operation known to surgery.

908. Boiling such water has the effect of precipitating the great excess of lime, but too much remains to render it desirable to use, if it can be avoided. For comfort sake, and to have perfect immunity from thirst, the less people drink of any thing the better; a moderate quantity (two cups) at breakfast, and the like at tea, are all that nature requires, and any one can soon become accustomed to this kind of moderation, by which the soundness of the stomach and the general health will be greatly promoted. Such persons are never dyspeptic, and never know the sensation of thirst, under any circumstances.

909. The tubes which secrete the mucus lie in the submucous (*sub*, under, beneath) tissue of the stomach; they are surrounded by the capillaries, which are going to form the capillary plexuses of the mucous membrane. These tubes open upon the floors of the gastric cells of the stomach; their number is variable, but they average from five to nine tubes in each cell.

910. A delicate distribution of capillaries with wide meshes runs around the tubes, and these are the vessels seen in those cells, presenting the most open surface, by which *stomach* may be discriminated from large intestine.

911. There is much obscurity surrounding the origin of the gastric juice; some authors supposing that it is secreted by the vessels of the mucous membrane of the stomach, but we now know that the stomach, in its submucous tissue, is literally filled with glands, hence called *gastric glands;* these all secrete a fluid, and while some of them are known to secrete the true gastric juice, the function of the remainder remains to be discovered.

912. These glands are not so well developed nor so conspicuous in man, as in other animals, and two views of them are selected, one from the Dog, and the other from the Calf.

913. In the pylorus of a Dog, large glands (Fig. 332) exist, lined with cylinder epithelium (*a*), and terminated by cœcal appendages (*b*); the body of the gland is shown at *c*.

914. The gastric glands from the middle of the stomach are those which secrete the gastric juice; the function of those of the pylorus is not known.

FIG. 332.

Gastric gland, Dog.

FIG. 333.

Gastric glands, Calf.

In the fourth stomach of the Calf these glands are particularly numerous, a portrait of which is given in Fig. 333. Like the gastric glands of the Dog, these also are lined with cylinder epithelium; there is an absence, however, of cœcal appendages at their termination, which becomes attenuated.

LESSON LXI.

NUTRITION IN MAN.

915. Before proceeding to describe the organs which, by their united action, form the nutrimental system of Man, it will be desirable to state briefly and succinctly the progressive order in which they are used, and the particular function delegated to each to perform.

916. The teeth may be divided into two chief kinds: *incisor* (or incision) teeth, placed in the front of the upper and lower jaw, their function being to primarily cut or divide the food; having done this, it is directly transferred to the second order of teeth,—the *molars*, or grinders, whose function it is to grind and subdivide the food as much as possible.

917. During the time the molars are thus employed, the saliva from the parotid glands is abundantly poured out from its ducts, which open opposite to the second grinder, and in the meanwhile the secretion from the other two pairs of salivary glands commingles with the first, and thus the food becomes thoroughly insalivated, whereby its living principle is destroyed, and incipient decomposition induced.

918. During this time the tongue is not idle—its business is to turn the food so that every surface of it may be presented to the molar teeth; neither is this all, for the tongue conveys the food from the molars on one side of the mouth to those on the other side, and when this first and most important operation is completed, the tongue conveys the food to the funnel-shaped cavity at the back of the mouth, called the pharynx, from whence it is passed to the œsophagus to be conveyed to the stomach.

919. The tongue is used by man in suction; the Canine and Feline races employ the tongue to lap fluids; the Giraffe twines this organ around the leaves and branches of trees, and detaches them with force. The Ant-eaters have a remarkably long tongue, covered with a slimy secretion; this they protrude, and upon it entrap their victims. The Cameleon among reptiles, and the Woodpecker among birds, have each a tongue enormously developed, for the purpose of prehension.

Fig. 334.

Human tongue.

It has been already stated that the human tongue, in common with the like organ in other animals, possesses three distinct kinds of papillæ; this will be best understood by consulting the subjoined figure of the human tongue (Fig. 334). The filiform papillæ are seen at *a*, the fungiform at *b*, and the circumvallatæ at *c*. That the filiform papillæ are endowed with the sense of taste is certain, from the fact that the gustatory nerves (nerves of taste) are extensively distributed to them; the precise function of the other papillæ is obscure. The white spots at the upper portion of the

tongue, above the circumvallate papillæ, indicate the mucus-crypts of Leiberkuhn, which are abundant in this situation.

920. The œsophagus is provided with two layers of muscles; one longitudinal, the other transverse.

921. By their united action the food is conveyed to the stomach, and delivered to what is called the cardiac orifice.

922. In form the stomach very much resembles the bag of a bagpipe, to which it is generally compared.

FIG. 335.

The human stomach.

923. It possesses three coats, an internal mucus, a muscular, and an external serous coat derived from the peritoneum, or the membrane which lines the muscles of the abdomen.

924. A figure of the external form of the stomach is given (Fig. 335); the œsophagus (*a*) enters the stomach at the cardiac orifice; the constriction at the other extremity marks the pyloric valve (*b*); and the first of the small intestines, the duodenum, commences on the other side the pylorus (*c*).

925. As soon as the food reaches the stomach, it comes in contact with agents which exert a chemical influence upon it; these are the gastric juice, and mucus. Stimulated by the presence of food, the muscles are in incessant action, constantly contracting on it, moving it from side to side, literally churning it.

926. The combined action of the heat of the stomach, the muscular action, and the solvent power of the gastric juice, aided by a peculiar influence of the mucus, reduces the food to its elements, or dissolves it into a pulpy state, called *chyme*.

927. In this form it makes application to pass through the pyloric valve, and if there be no solid particles, it is permitted so to do; but undigested matter is sent back again to be thoroughly reduced before it can be allowed to go through the valve into the duodenum. If, however, the food chance to be of an unhealthy or indigestible character, the stomach soon casts it out, in the same state that it entered the organ, and proceeds to act upon what may remain of a better character.

LESSON LXII.

NUTRITION IN MAN, CONTINUED.

928. When it reaches the intestine, the chyme is subject to new influences; the Liver supplies its bile, and the pancreas (or sweet-bread) the pancreatic juice, and by their means the *chyme* becomes changed into *chyle*, or new blood, which is to circulate throughout the body, to renew wasted material, and to promote growth.

929. When formed, the chyle is white and milk-like, and is associated with innutritious materials; from these it is separated, firstly, in the duodenum, and what then escapes is subsequently constantly being separated throughout the tract of the small intestines.

930. But the chyle is not blood; it does not yet possess the necessary requirements of that fluid—it has no life; it wants, in fact, another element, oxygen, and must go to the lungs to obtain it. For this purpose the villi of the small intestines are provided with certain tubes, or canals, called lacteals, from lacta, milk, and it is their duty to take up or remove the chyle, still white, and convey it upwards to a reservoir in the chest called the thoracic duct; thence to the heart, and finally to the lungs, from which latter organ it is returned to the other side of the heart (the left side), of a beautiful bright vermilion color, endowed with all the properties of new blood, and forthwith to be distributed by the arteries to all parts of the body, for the purposes of nutrition.

931. The injected preparation of the mucous membrane of the stomach of the human subject (Fig. 336) is a magnificent spectacle! Here we have a dense arrangement of honeycomb-like cells, the walls of which are formed, not of a single capillary as we have hitherto seen, but a plexus of very delicate vessels. This particular arrangement is only met with in the mucous membranes of man, and the monkey; in all other animals single vessels form the cell walls; by this sole characteristic the human stomach (or monkey) may be readily known.

FIG. 336.

Mucous membrane of human stomach.

932. The commencement of the duodenum, soon after its junction with the pylorus, abounds in glands, known as "Brunner's glands," from their supposed discoverer; in truth, however, these, in

common with the remainder of the intestinal glands, were really discovered by Peyer, who describes them as being "as numerous as the stars in the firmament of heaven."

933. These glands lie, not in the mucous but in the submucous tissue, where they form a continuous layer of white, flat bodies, of irregular size, surrounding the whole intestine. Each gland consists of numerous minute lobules, of which the ducts (*a*) open into the mucous membrane of the intestine. A figure of these glands is given (Fig. 337).

FIG. 337.

Brunner's glands.

934. The villi of the duodenum (Fig. 338) are usually larger and broader than those of the Jejunum, and are remarkable for the possession of a large vessel in the centre of each villus; throughout the small intestines, at the bases of the villi, and surrounding them, are the mucus-crypts, or follicles of Leiberkuhn.

935. They appear like so many minute holes upon the surface of the mucous membrane; examined by dissection, they are found to be long, narrow, deep tubes, or cavities, giving the idea of a villus pushed into the mucous membrane, and inverted, like inverting the finger of a glove. In life these glands are filled with a clear, fluid secretion, called the *intestinal juice*.

FIG. 338.

Villi, of human Duodenum.

FIG. 339.

Jejunum, human.

936. In the human jejunum the villi and Leiberkuhnian follicles are well seen (Fig. 339); it will be readily perceived that, by the arrangement of these follicular glands, the surface of the mucous membrane is thereby greatly increased; where there is not room for another villus, there is yet room for a series of minute apertures at its base.

937. The villi of the small intestines contain in their interior

certain vessels, whose function it is to absorb the nutriment and convey it into the circulation, to supply the blood positively lost by the various glandular bodies, all of which have secreted or formed something from it; these are the lacteals, already referred to.

LESSON LXIII.

NUTRITION IN MAN, CONTINUED.

938. The precise relation of the lacteals to the villi of man, has not yet been determined, owing to the difficulty of meeting with villi distended with chyle; but in the lower animals we can feed, and subsequently kill, at any required moment, a Dog, or Cat, &c., and at once proceed to make the necessary examination.

939. These vessels appear to be much larger than capillary blood-vessels, and one only is found in a villus which traverses its central axis, and terminates in a cœcal, or enlarged end.

940. But how does the chyle get into the lacteals? This is a very difficult question to answer, and one to which no satisfactory reply has yet been given. Many theories have been advanced, but no authenticated observations have as yet been published.

941. Some investigations made on this subject,* but not yet given to the world, lead to the conclusion that the apices of the villi open, and that the chyle is received directly in at the enlarged termination of the lacteals; it must be conceded, however, that this fact is very difficult of verification, for the tissue, when first seen, is covered with a deep layer of mucus: the epithelium at the summit of the villi, is, like the organs themselves, porrect (standing up), and worse, it so soon dies. The only favorable circumstance in connection with a transient glance is, *the uprightness of the villi*, so that the spectator looks down upon and readily perceives their open

* Thirty years ago, during the Author's studentship, desirous of obtaining information on this subject, he killed a Cat, and proceeded to examine the small intestine as rapidly as possible, whilst yet vitality remained in the tissue. He saw the summits of the villi *all open*, apparently as wide as their own diameter, but they soon closed up, and remained shut.

Subsequently he repeated this experiment to a party of distinguished medical men, in London, including some of his teachers.

Having to arrange the preparation under the microscope, he again saw the same sight, but, owing to the rapid loss of vitality, the villi so soon closed that not more than two or three of the gentlemen present had an opportunity of seeing any thing of this interesting exhibition, and then so hastily that it was far from satisfactory to them. He has not since repeated this experiment.

mouths, but such experiments need confirmation at the hands of other observers, before they can be received as true.

942. The human Ileum is chiefly remarkable for the number of solitary and agmenated glands there found. The former are in every respect like the latter, except that they are scattered amongst the villi singly, instead of being grouped in masses.

943. These glands are rounded, flattened organs, always found along that surface of the intestine which is opposite to the mesentery. The "Peyer's patches" of these glands increase in size as they approach the cœcum, and attain their greatest dimensions just within the iliac portion of the valve which separates the ileum from the cœcum—ilio-cœcal valve.

944. Each gland of a Peyer's patch is round, somewhat hemispherical, but slightly flattened at the top; no vessels have been detected in them, except in the preparation of the Calf (Fig. 386), where, it is supposed either that the gland was in some peculiar condition, or that the form of injection used (Bi-chromate of potash) ran more minutely than usual; most likely the latter.

945. They contain a thickish gray matter, with which there is but little fluid, and a number of nucleated cells, of round form, together with an abundance of free nuclei. A figure of the aggregated glands (Fig. 340) is given; the glands are seen at *a*, and the villi of the intestine at *b*.

946. These glands are particularly liable to take on disease in typhoid fever, and patients are frequently convalescent of the fever, and yet die of *Typhoid Peyerian glands.* When this disease supervenes, the glands firstly ulcerate, and subsequently slough off, destroying at last the walls of the intestine—when the patient dies.

FIG. 340.

A "Peyer's patch," from the ileum, human.

FIG. 341.

Typhoid Peyerian glands, human.

A figure of typhoid Peyerian glands, copied from a preparation, is here given, (Fig. 341.) The healthy villi of the intestine are seen at *a*; at their bases lie the follicles of Leiberkuhn (*b*), whilst a large

hole (white in the preparation) shows where the glands of Peyer have sloughed off. In phthisis these glands are liable to become the seat of tubercular deposit, and also of an ulcerative process, whence results the diarrhœa, so troublesome in that disease. In Asiatic cholera they become greatly enlarged from the accumulation of granular matter in the vesicles.

Brunner's glands are remarkably free from tendency to disease.

947. The mucous membrane of the large intestine in man, as in other animals, bears a close resemblance to the like tissue of the stomach, but in man (and the Monkey) again we find that a delicate plexus of capillaries, not single vessels, forms the boundaries of the cells (Fig. 342).

FIG. 342.

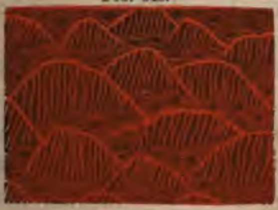
Human Colon.

948. Solitary glands are abundantly found in the large intestine; they are of large size, and exhibit a funnel-shaped cavity (see Fig. 293) or pit-like aperture, which forms a depression of the mucous membrane; at the bottom of this follicle lies a closed, somewhat flattened gland, exactly the same in structure, and possessing similar contents to the glands of the small intestines.

It has already been observed that the mucous membranes in the Monkey are identical with similar structures in man, and two illustrations are offered in confirmation of this fact.

The first (Fig. 343) is from the Jejunum, and exhibits villi of

FIG. 343.



Jejunum, Monkey.

FIG. 344.

Colon, Monkey.

the same size and shape, and the same display of mucus-crypts, as the corresponding human intestine.

The second (Fig. 344) is from the Colon, and again the same exact parallelism exists. While the cells of such tissue in all other animals are surrounded by single vessels only, it is reserved for man and the Monkey to display a *plexus* in the same situation.

949. A carefully compiled description has thus been given of the form of the nutrimental organs, and their accessory glandular appendages, in the several classes of the animal kingdom, commencing with the lowest, and tracing its gradual development up to man.

LESSON LXIV.

NUTRITION IN MAN, CONTINUED.

950. In the class of ANIMALCULA, we saw a number of digestive cavities possessing but one opening; a little higher in the same class, this cavity was extensively sacculated.

951. In the ROTIFEROUS animals, the alimentary canal possesses two openings, and a glandular apparatus is superadded.

952. The ENTOZOA (intestinal parasites) are somewhat anomalous; the *Acephalocyst*, although allied to the Entozoa by its affinities, is really lower than the lowest animalcule. It is provided with a nutrimental cavity, but destitute even of a mouth, and like the plants, to which it is most closely allied, propagated by spontaneous division. None of the Entozoa possess more than one cavity to their nutrimental organs.

953. In the POLYPI we found the same simple condition of the nutrimental canal, and in those which possess a stomach with two cavities, the lower one is solely devoted to the transmission of nutriment for the extension of the commonwealth.

954. The ACALEPHA are equally simple, and the like must be said of some of the

955. ECHINODERMATA, where Asterias possesses only one digestive aperture.

956. In the remaining orders, a slight advance has been made; the alimentary canal is much more extensive, possesses convolutions, and terminates in a distinct aperture, opposed to the mouth.

957. Amongst the lowest of the ANNELLIDES ranks the Leech; but although possessing only a stomach furnished with cœcal appendages, it has yet two apertures. The Aphrodita, in addition to its numerous cœca, has an intestine superadded.

958. In the lowly EPIZOA, we still have two apertures to the alimentary canal, in addition to an intestine, which indicates a higher grade of development.

959. In the CIRRIPEDS the same condition obtains.

960. The CRUSTACEA mark a higher advance, by the possession of a large, well-developed liver, in addition to an intestine and two apertures.

961. The INSECTS are truly remarkable for the great perfection which their organization displays. Provided with mouths exquisitely adapted to their varied food, the structure of their internal organs is quite complicated.

962. Here we meet, not only with salivary glands, but frequently existing to the extent of three pairs of them—as many pairs as man himself possesses, and endowed, apparently, with similar functions. In addition, they all have a liver, and some of them (Blatta) a pancreas, whilst the intestinal canal is divisible into nearly as many portions as that of the human subject; and, finally, many of them possess kidneys.

963. The higher members of the class ARACHNIDA, the Spiders, have a liver and a kidney.

964. In the MOLLUSCA we find no advance, but in many of its members a falling off of development.

965. In the TUNICATA, the only accessory organ is a liver. The like in the BRACHIOPODA and LAMELLIBRANCHIATA. In the GASTEROPODA, salivary glands are added.

966. The CEPHALOPODS, like many Insects, have a plurality of stomachs, but no positive advancement is discernible; as a whole, the class Mollusca appears to be below the Articulata in general organization.

967. The FISHES, as the lowest class of the Vertebrate sub-kingdom, exhibit only a rudimentary condition of the nutrimental organs; a liver, however, is always found, and usually well developed; the salivary glands, for the most part, merge into the pancreatic follicles so abundantly developed in the majority of them.

968. The REPTILES, as a class, indicate a higher rank; the stomach is always well formed, particularly as regards the internal structure of it; neither are the accessories of a well-defined nutrimental function wanting. Although the Frogs are destitute of salivary glands, the three pairs common to the higher animals are distributed amongst the other members of the class. They are all supplied with a liver, have the intestinal canal of sufficient length and properly divided, and possess kidneys.

969. The BIRDS, amongst their remarkable developments, possess, many of them, four pairs of salivary glands. Without jaws,

without teeth, for the dividing and mastication of their food, the stomach is wonderfully modified to suit an extraordinary want. All the other requisites of a well-developed nutrimental function they are possessed of.

970. The most elaborate and perfect form of these organs is met with in the class MAMMALIA. Notwithstanding the various modifications and complications of the nutrimental canal to meet special wants, the general principle remains always the same, and the several accessory organs essential to perfect digestion of the several kinds of food, upon which the members of the class are destined to subsist, are there.

LESSON LXV.

NUTRITION IN MAN, CONCLUDED.

971. What a wonderful piece of mechanism is the human intestinal tract, with its millions of villi all periodically actively engaged, its mucus-crypts, its countless glands, its capillary, and its nervous systems! That it should at any time get out of repair is by no means surprising; the wonder is that it remains in a healthy condition, especially from the difficult and impossible labors many of us call upon it to perform. The true rules for a sound and healthy stomach are few and simple—*to eat when we are hungry, and to drink only when nature requires it.*

972. How many persons there are who occupy themselves incessantly in eating, and as incessantly in drinking water! Has it ever occurred to them that the highly complicated machinery necessary to digest food requires repose?

973. The muscular coat of the stomach having labored to digest a meal, demands rest, and must have it, if its vigor be cared for. On the other hand, if it be attempted to make the necessary organs always work, they flatly refuse, and will not do any thing; whereby the worst form of dyspepsia results. A pint of water weighs one pound, and the stomach must attempt the same means to get rid of it as though it were the same weight of solid food, but with less success; all its contractions are in vain—the water eludes these efforts till the fatigued muscles yield in despair.

974. But there are other forms in which we do ourselves a great wrong, namely, by eating improper, because indigestible food, or by eating food improperly prepared. Thus young meats (Veal and

Lamb) are neither nutritious nor easy of digestion; Beef, and especially Mutton, are by far the lightest and most nutritious of all meats.

Curious, but most satisfactory information, quite confirmatory of the views already enunciated, have been furnished by a series of carefully noted experiments, made at different times, and by a number of independent observers, upon the stomach of Martin, the celebrated Canadian with a permanent hole in his stomach, the result of a gun-shot wound. The gastric juice, long supposed to be a myth, inasmuch as no one had ever seen it, because it cannot be found in death, appears to be secreted at the very time, and in the exact quantity wanted. The physiological law that all young meats are indigestible, is sustained by the fact that a tender young Chicken requires two-thirds longer time to digest it than a tough old hen. Chickens are frequently prescribed for invalids, but this appears to be a mistake, as, to be easy of digestion and nutritious, the full development of age would seem to be essential. But care and caution are necessary in the preparation of such food; it should be put into cold water after having been cut into pieces, and simmered gently for many continuous hours, the time required depending upon its age. If it once be suffered to boil, there is an end of the process, for muscle consists of the two elements—albumen and fibrin—and the too sudden application of heat, or the temperature of the boiling point, *coagulates* one element (albumen), and *corrugates* the other (fibrin).

Coagulation of albumen is the state to which the white of an egg is reduced when boiled hard—perfectly solidified. Corrugation of fibrin is imitated by parchment brought under the influence of a strong fire, in which the entire mass is shrivelled, or clewed up into a small space; in both cases the nutriment is locked up, and rendered inaccessible to any stomach.

The flesh of an Ox or Cow is more readily digested than Veal; Mutton, than Lamb.

It is well known that the application of heat to butter or lard decomposes them, and essentially alters their properties; for this reason pie-crust is extremely unhealthy. A peep into the Canadian's stomach, shows conclusively that cooked butter or lard is firstly separated; it then floats upon the surface as a mass of grease, and ultimately passes out of the stomach, without undergoing any digestion whatever.

The skins of all kinds of fruit are entirely indigestible; the stomach refuses to have any thing whatever to do with them.

Hot bread never digests at all; after a long season of working and tumbling about the stomach, it will begin to ferment, and in the end, having submitted the organ to a great amount of fatigue, be finally passed out of the stomach as a refractory and unmanageable mass. But it never becomes assimilated, or absorbed by those organs destined to appropriate nutriment.

Another remarkable fact has been developed, which proves the truth of the old adage, "laugh and grow fat." It has been satisfactorily established that mirthfulness at and after a meal greatly facilitates digestion. On the other hand, if this man be made angry at or immediately subsequent to a meal, bile rushes into the stomach in a perfect stream, and digestion is retarded for some hours, and at last feebly performed.

975. Besides hot, there is another form of bread demanding notice, and the evils in connection with it are easy of demonstration; for example: the bones of a young Child are gelatinous (composed of jelly), or, at the best, cartilaginous (gristly); to become bone, they require the phosphate of lime to be deposited in the meshes or interstices of the tissue.

976. Wheat contains the phosphate of lime, which, if allowed to remain as such, would be duly appropriated; but if *alum* form a constituent of bread, this earth is neutralized, for a mutual decomposition takes place between it and the constituents of alum. Alum is the earth *alumina*, in combination with *sulphuric acid;* but if phosphate of lime be present, the sulphuric acid having more affinity for lime, quits the alumina, and forms a new compound—sulphate of lime, or plaster of Paris. The phosphoric acid and alumina are both set free, and in the way of nutrition. Children fed upon bread thus made are liable to rickets, caries (rotting) of the teeth, and a still worse disease known as "spina ventosa," in which very painful tumors are formed, sometimes as large as a human head.

977. Another very objectionable substance is in general use, to supersede eggs, or yeast—saleratus; it is only necessary to remind the reader, that this agent is simply a modified *pearlash*, which is a poison.

978. But it is not only in the baker's bread that we go wrong; it has been already remarked, that the hot *biscuits* in common and daily use are most objectionable, and no stomach can possibly digest them; moreover, they are rarely sufficiently baked.

979. Every good housewife knows, that whilst a loaf from the baker is scarcely eatable on the second day, that her own sweet,

pure, and nutritious "home-made," retains its freshness and softness for at least a week,—this is the best form of bread.

980. Unripe fruit and vegetables should be avoided as dangerous; consequently *green corn*, being an unripe, immature vegetable, is most unhealthy.

981. Those persons who partake of this vegetable, are constrained to eat the hull, which, in the green state, is particularly thick and tough, and cannot possibly be assimilated, as the experiments on Martin's stomach fully testifies; moreover, the corpuscles of starch, so eminently desirable in the ripe corn, are not yet formed in its green condition. Never eat or drink between meals.

982. These remarks might be extended with great propriety, but the theme is neither a gracious nor a pleasant one; it must be understood, at the same time, that they are addressed ostensibly to the younger members of the community, who will feel no difficulty in beginning the right way, and continuing in it, whereby their life will be prolonged, and their happiness promoted.

LESSON LXVI.

COMPOUND TUBULAR TISSUES.—MUSCULAR FIBRE.

983. The flesh of animals is called technically *muscle;* examined by the microscope it is found to be of two distinct formations—*striped*, and *non-striped*. The majority of the lower animals, especially those (*Mollusca*) in which the nutrimental function is developed at the expense of those properties which commonly distinguish an animal, as locomotion, volition, &c., possess the non-striped muscle only.

984. Insects, Crustacea, and other of the animals conspicuous for their activity, possess, in addition to the non-striped, the striped muscle.

985. In the lower, in common with all the higher animals, the non-striped muscle belongs to the vegetative organs (nutrimental canal); and the striped muscle to the organs of animal life (locomotion).

986. A singular and beautiful illustration of the muscular fibre of the Molluscous class may be given from a specimen of *fossil muscular fibre*, from the tentacles of the extinct *Belemnite*, which accu-

rately agrees with the structure of the muscular fibre of the tentacles of the recent Cuttle-fishes (Fig. 345).

987. The fibres are of two sizes, those near the external surface are remarkably fine (*a*, Fig. 345), whilst those of deeper layer (*a*, Fig. 346) are much broader; both present the same characteristics, which consist chiefly in the possession of a great number of nuclei (*b*, Fig. 345). Wherever two layers of fibres are found (in the deep-seated muscle), one layer of fibres crosses the other at right angles (*c*, Fig. 346). The fibres of the outer layer show the pigment cells in great abundance, and in a wonderful state of preservation (*a*, Figs. 346 and 347).

FIG. 345.

Fossil muscular fibre, Belemnite.

FIG. 346.

Fossil muscular fibre, Belemnite.

FIG. 347.

Fossil muscular fibre. *a*, Integument, Belemnite.

988. In addition to the muscular fibre, a portion of the integument (*a*, Fig. 347) is also shown; it occurs to some extent in connection with the muscular fibre, in which situation it cannot well be seen, but the detached portion is very interesting, as it shows epidermic scales. In this preparation the fibres are seen singly, and the nuclei well shown.

989. Amongst the active animals of the Articulate sub-kingdom, the striped fibre prevails, except as regards the muscles of the nutrimental organs. This form of the fibre in insects, and Iulidæ, has often been figured, but a general misconception appears to prevail with regard to its true structure.

990. The transverse lines on an insect fibre are so well marked,

that they give an idea of coarseness, and as such they have been described; but a little careful examination of the subject will show this opinion to be erroneous, for, on the contrary, the ultimate fibrillæ in these animals are so remarkably delicate, that no amount of magnifying power will succeed in showing a single transverse line upon them, when examined singly—in the mass they are seen.

991. This is shown in Fig. 348, copied from a preparation of the muscles of Blatta Americana, made to show the ultimate fibrillæ; the muscular fibres on either side (a, a) show delicate transverse lines, but the fibrillæ torn from, and still connecting them (b), do not show the least indication of a transverse line, still they are really there.

992. So, too, Iulus (Fig. 349), in which the lines on the fibre are very coarse, the fibrillæ liberated at the end, are singularly fine, and display no transverse lines.

FIG. 348.

Muscular fibre, B. Americana.

FIG. 349.

Muscular fibre, Iulus.

993. If we examine a muscle of the higher animals by the naked eye, it will be seen to consist of a bundle of fibres, running in the direction of the long axis of the muscle, and connected by means of areolar tissue.

994. If a *muscle* be analyzed by dissection, it will be found to consist of *fasciculi*, or bundles of fibres; and if we succeed in obtaining an *ultimate fibre*, it will consist of a fasciculus or bundle of *ultimate fibrillæ*.

995. An *ultimate fibre* exhibits, under the microscope, the longitudinally arranged fasciculi of *ultimate fibrillæ*, their number being so great, however, that their precise structure cannot be determined until separated.

LESSON LXVII.

MUSCULAR FIBRE, CONTINUED.

996. In addition to the longitudinal lines, equi-distant transverse lines, at right angles to the former, will also be seen, and the

general appearance of the fibre will indicate a breaking up of the entire structure into small dice, or square cells containing discs.

997. It is always uncertain in which direction a muscle will prefer to split—whether in the direction of its longitudinal elements, the fibrillæ, or in the direction of the transverse lines—the cells. A representation of cleavage in the latter direction may be seen at Fig. 350.

Fig. 350.

Muscular fibre cleaving transversely.

998. It has been remarked that the elements of a muscle (fibres) are connected to each other by areolar tissue; the elements of a fibre (ultimate fibrillæ) are similarly connected; but a *fibre* is enveloped in a distinct and characteristic tissue—the *myolemma* (sheath of the muscle), or simple membrane in the animal kingdom.

999. This sheath is quite distinct from areolar, or any other tissue. Its existence can easily be demonstrated in any muscular fibre by subjecting it to the action of fluids, which occasion a swelling of its contents; such is the effect of acids and alkalies, and the result may be obtained by citric and tartaric acids, or by potash.

1000. There is no reason to believe that the myolemma is perforated, either by nerves or capillary blood-vessels; it rather seems to present an impenetrable barrier between the real elements of muscular structure and the surrounding parts.

Fig. 351.

Vascularity of muscle. *a*, Artery; *b*, Vein; *c*, Capillaries.

1001. Muscular tissue, properly so called, is extra (non) vascular; for its fibres are not penetrated by vessels; and the nutriment required for its growth must be drawn by absorption through the myolemma.

1002. Still, the substance of muscle, as a whole, is remarkably vascular; the capillary vessels being distributed in parallel lines, running in the direction of the fibres, and united by transverse branches in the minute interspaces between the fibres; so that, in all probability, there is no fibrilla which is not in close relation to a capillary (Fig. 351).

1003. The *striped* muscles, or muscles of *animal life*, as they

are called, in contradistinction to the *non-striped* muscle, or muscle of vegetative or *organic life*, are, of all the tissues except the skin, most abundantly supplied with nerves. These, like the blood-vessels, lie on the outside of the myolemma of the several fibres; and their influence must consequently be excited through it.

The general arrangement of the nerves is shown in Fig. 352.

FIG. 352.

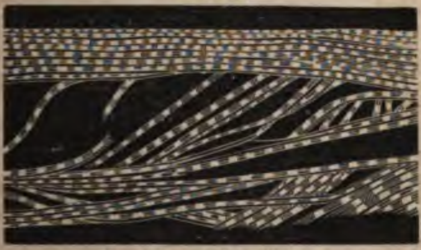
Distribution of nerves to muscle.

1004. The ultimate fibres or tubes of the nerves, after issuing from the trunks, form a series of loops, which return either to the trunk from whence they proceeded, or to an adjacent one.

1005. Having described the general structure of the striped muscle, it only now remains to give its minute and ultimate characters.

1006. Obtain by tearing out the tissue an ultimate fibril, or tear a fibre longitudinally, so that it is held together only by a series of fibrillæ, such as represented in Fig. 353.

FIG. 353.



Muscle torn to show fibrillæ.

FIG. 354.

Ultimate fibrilla of muscular fibre, Pig.

1007. Place it under the microscope, using for this purpose not less than a fourth object-glass—or a linear power of about 500 diameters.

1008. An appearance such as is shown in Fig. 354 will be seen.

The fibrilla will now appear to be a delicate transparent tube, divided by well defined but very delicate transverse lines, by which the structure is broken up into a series of symmetrical cells.

1009. In the centre of each cell is a solid, dark body—the *sarcous element* of Bowman.

1010. A fourth object-glass will only show a single transverse line; but a superior twelfth object-glass will show that the line is double—divided by the least conceivable interval of space.

1011. If the structure be built up of cells (of which there appears no room for doubt), each cell should have an upper and lower portion, and the approximation of two cells should show the top of the one and the bottom of the other, and this is true.

1012. The transparent membrane around the sarcous element has been named the sarcolemma (sheath of the fleshy element).

1013. Thus it will be seen that a primitive fasciculus is made up of a number of fibrillæ, running together in a longitudinal direction, united together by areolar tissue; when a fibre is formed, the entire fasciculus is contained in the peculiar sheath, the myolemma.

Each fibrilla is again composed, as before stated, of an external tubular sheath, the sarcolemma, in which is contained cells having rectangular discs (sarcous elements) enclosed in chambers, or spaces, formed by processes of the sarcolemma extending across the tube. The fasciculi are united in bundles by areolar tissue, invested by the myolemma to form the fibres of descriptive anatomy.

LESSON LXVIII.

MUSCULAR FIBRE, CONCLUDED.

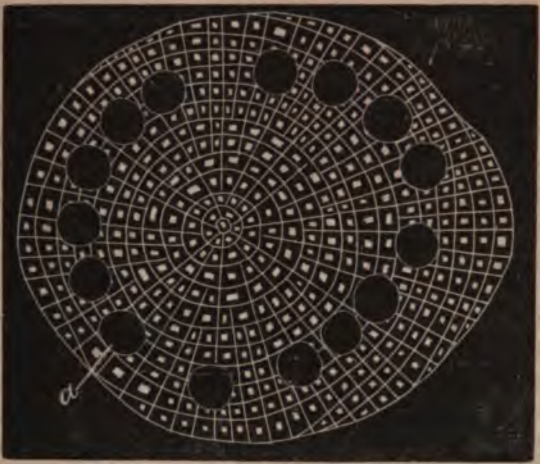
1014. Such is the history of the structure of the muscular fibre of animal life, and when compared with the representations of fresh-water and marine algæ, they will be seen to be identical.

1015. Thus Fig. 355 represents a very beautiful parasitic fresh-water Alga, found upon the stems and leaves of the white and yellow pond-lilies. The entire structure consists of a congeries of square-shaped cells, each of which is a plant in itself, and containing an equally square nucleus, or germinal spot.

1016. It should be remarked that the squareness of the cell, and of the nucleus, form distinctive characters of this order of plants.

1017. The series of large, dark, circular masses (*a*) around the figure, and near the margin, are the *sporangia* (*spora*, a seed; *aggos*, a vessel; spore, that portion of a plant which performs the function of seeds).

FIG. 355.



Fresh-water Alga, parasitic on pond Lilies.

1018. In this order of plants propagation is effected by the spontaneous division of cells, and by spores, contained in what is called "mother-cells" (perispores), the structures described (*a*) in the figure.

FIG. 356.

Callithalmia Baileii.

FIG. 357.

Alga, from Barbadoes.

1019. In a beautiful Marine Alga, *Callithalmia Baileii*, its specific name, in honor of the late Professor Bailey, of West Point,

we find an approximation to the structure (ultimate) of muscular fibre (Fig. 354). The plant consists, like all the algæ, of a congeries of cells of exceedingly variable size, depending upon their maturity.

1020. A bud is shown, made up of cells equally variable in size. In the interior of all these cells, without exception, is a nucleus, of a reddish brown color, always bearing a close relation to the size of the cell containing it (*a*).

1021. In another marine alga, from the Island of Barbadoes (Fig. 357), we appear to be gazing upon a very highly magnified ultimate fibre of the Pig. The arrangement of the longitudinal lines, indicating ultimate fibrillæ, is *perfect*, and the cells, somewhat longer in one diameter than in the transverse one, and containing the (as if) sarcous elements (*a*), renders the illusion as satisfactory as can well be desired.

1022. But a still closer approximation is in store for us; in Lake Michigan, at Chicago, may be found, in great abundance, a remarkably delicate fresh-water alga. Like all its kindred, it exhibits, at the same moment, every stage of development. Small, detached portions of this plant are extremely graceful in the general arrangement of their parts, as will be seen by reference to the figure (Fig. 358).

Fig. 358.

Alga from Lake Michigan, Chicago.

1023. This plant, collected in the height of summer, gave indication of its amazingly rapid growth, all the cells, devoid of nuclei, indicating new cells; the cells of the stem, however, are more mature than those of the branches, and each one contains a nucleus (*a*).

1024. It is only necessary to refer the reader back (Fig. 354) to the highly magnified view of the ultimate fibrilla of muscular fibre, and making due allowance for the dis-

parity of size in that figure and this, there can be no doubt that the structure is the same.

1025. It is by no means the least remarkable fact that a tissue purely animal, as is the muscular fibre of animal life, should exhibit in its elements the true characteristics of a vegetable origin, and, still more, of a lowly vegetable, such as an alga, but here we may trace a distinct connection between the lowest plants and even the highest animals.

1026. The ultimate element of a muscle, therefore, is a single nucleated cell, such as forms the sole element of thousands of plants.

1027. Neither does the analogy end here, for it is well known that in muscular fibre the cells are firstly formed, and the nucleus (sarcous element) subsequently placed therein.

1028. It is highly probable that the sarcous elements of muscle possess the same generative power as the nuclei of plants, and that the tissue is extended by the subdivision of the sarcous element, and the cell containing it.

1029. Very thin transverse sections of muscle show merely a series of minute round dots—the sarcous elements—each one being surrounded by a small circular white ring, denoting the position of the rectangular body within the tube (Fig. 359).

FIG. 359.

Transverse section of muscle.

1030. The muscles of organic life, or *voluntary* muscles, as they are called, differ in structure from the preceding.

1031. They form a closer and more compact tissue, and are far more difficult to manipulate with than the muscles of animal life.

1032. It sometimes happens that their size is *less* than the fibres of the striped muscle, although in some animals the contrary is the fact.

1033. These plain, non-striated fibres, are arranged like the fibres of the other muscles, in a parallel manner, into bands, or fasciculi; but the fasciculi are usually woven into a network not having any fixed points of attachment.

This is the nature of the muscular coat of the œsophagus, stomach, intestinal canal, &c.; it also occurs in most of the large gland ducts, and in the iris (curtain of the eye).

1034. The Heart is composed of various forms of muscular fibre; some being distinctly striated, others quite plain, and others of intermediate character.

1035. The chief characteristic form of the non-striped muscular

fibre consists in certain *nodosities* (bullæ), developed at certain intervals, and these are found to contain a *nucleus*.

FIG. 360.

Non-striped muscular fibres.

1036. To render this latter fact apparent, it is frequently desirable to employ acetic acid, but preparations are not uncommon which have not been subjected to the action of any re-agent, but in which the nuclei are well seen. A figure of the non-striped fibre is given (Fig. 360).

1037. The true structure of muscular fibre, as revealed by the microscope, was first published in the Philosophical Transactions, by Mr. William Bowman, and that account has been made available, in addition to original observations and preparations.

LESSON LXIX.

COMPOUND TUBULAR TISSUES, CONTINUED.—NERVOUS SYSTEM.

1038. The late Baron Cuvier applied himself to correct the errors in the classification of Animals which had been handed down to us by Aristotle, the Father of Natural History, altered, but not improved, by Linnæus, and descended to our own times.

1039. To this end he devoted much time and untiring labor to the dissection of the nervous systems, especially of the Invertebrate animals. The result of these labors was, the division of the entire animal kingdom into *four primary divisions*, or sub-kingdoms.

1040. Notwithstanding that the structure of the nervous system really formed the basis of his classification, he contented himself with the prominent external characters, as the means of designation of his three lower classes, and only in the first class is an *internal* character adopted.

1041. Thus the animal kingdom consisted, according to this author, of the following divisions:

VERTEBRATA,	ARTICULATA,
MOLLUSCA,	RADIATA.

1042. All the animals of the first class possess a bony vertebral column, for the transmission and protection of the spinal chord.

1043. The MOLLUSCOUS animals were so called from the general softness of their bodies, such as slugs, snails (marine, fresh-water, and terrestrial), the inhabitants of bivalve (*bis*, two) and univalve

(*unus*, one) shells, and the many forms of naked similar creatures found in the ocean.

1044. The ARTICULATA have their bodies composed of a variable number of distinct rings, or segments, jointed to each other, such as *Lobsters*, *Insects*, *Centipedes*, *Worms*, &c.

1045. The RADIATA are so called from the several members of the body radiating from the central portion, as in the Star-fishes.

1046. Dr. R. E. Grant, of Edinburgh, offered, some thirty years ago, a classification of the animal kingdom which should be based upon the development of the *nervous system alone*. Hence the new classification, as compared with Cuvier's, stood thus :

1047.	*Cuvier.*	*Grant.*
	VERTEBRATA,	SPINI-CEREBRATA.
	MOLLUSCA,	CYCLO-GANGLIATA.
	ARTICULATA,	DIPLO-NEURA.
	RADIATA,	CYCLO-NEURA.

1048. The Cerebro-spinal (*brain, spine*) axis of man, and all Vertebrates, originated the expression by which Grant designates this sub-kingdom.

1049. The Mollusca were assumed by this author to possess a nervous chord which surrounded the œsophagus, and upon which ganglia were placed ; hence *Cyclo-gangliata* (circle ; ganglions.) The nervous system of Cuvier's Articulata is found to consist, primarily, of a *double nervous chord*, hence *Diplo-neura* (two ; nerves), but on which ganglia are more or less found.

1050. The last sub-kingdom, the Radiata of Cuvier, presents (in the Star-fishes, according to Tiedemann) a nervous ring surrounding the oral aperture, but *without any ganglion*, therefore *Cyclo-neura* (circular nerve).

1051. This classification was unquestionably *an advance;* but another man, younger than Grant, and newer to science, desired to *prove the facts* upon which the latter system was founded, and this man was Owen.

1052. With regard to the Vertebrate division but little could be done—Cuvier's characters had covered the ground, and the nervous system was found to be arranged on a uniform plan.

1053. However, in place of the " Spini-cerebrata" of Grant, Owen proposed *Myalencephala*, as somewhat more expressive, the word being derived from *muelos*, marrow, and *egkephalon*, brain.

1054. When the learned professor examined the *Molluscous* animals, he found Grant's character to fail; in this class a nervous

ring, beset with ganglia, is *not* found, except in rare cases; it is a *nervous commissure* (or band) *connecting the cephalic ganglia*, and passing, not *around*, but *behind* the œsophagus. Then the *pedal* ganglia (in those molluscs possessing a foot) and the *branchial* ganglia are variously disposed—now in one place, now in another—hence Owen, with far greater propriety, called Cuvier's Mollusca, Heterogangliata (*eteros*, other; *genos*, kind).

1055. The designation of the next sub-kingdom, by Owen, as compared with Grant, is of less consequence; and whether we express the "double nervous chord" with Grant, or speak of the symmetrical arrangement of the ganglia in this class, with Owen, who calls them, from the latter circumstance, Homogangliata (*omes*, the same; *genos*, kind), matters not, either expression being equally correct.

1056. We come to the last division of the animal kingdom, *Radiata* of Cuvier, *Cyclo-neura* of Grant.

1057. Owen is content to take the statement of Tiedemann in relation to the Star-fishes; moreover, he has a preparation of Asterias papposa, in the college Museum, prepared by the hand of the immortal Hunter, but whether the author designed it to represent the *nervous system* (which it certainly does not), or a portion of the *vascular* system (which it assuredly does), is left to conjecture.

1058. For those animals of the *Radiate* division in which Owen believes a *nervous system* has been recognized, he proposes the word *Nematoneura* (*nema*, a thread; *neuron*, a nerve). But in common with many others, he is by no means satisfied that a nervous system has been discovered in some of the class of Cuvier's Radiata; and for these he proposes a very significant designation—*Acrita*, confused.

1059. The lower animals exhibit all the *manifestations* of a nervous system, whether it can be detected or not.

1060. It is presumed, therefore, *to exist*, but under such circumstances that even the microscope fails to detect it as an independent organism—it is *diffused* or *confused*, and hence the expression is a good one.

LESSON LXX.

NERVOUS SYSTEM, CONTINUED.

1061. The classification of the three first classes of the animal kingdom, especially by the last authority, is undeniably good; much doubt exists, however, as to whether a nervous system really exists in any individual of the last (Radiata) or not.

1062. John Hunter left a preparation in his Museum of *Asterias papposa* (a many-rayed Star-fish); a white, delicate ring is seen surrounding the oral (mouth) aperture, from which a series of white chords are traced into the several rays; this has been assumed, by his successors, to be the nervous system—Hunter's notes, in relation to his preparations, having been destroyed.

1063. Subsequently, Tiedemann published a valuable monograph on the *Echinodermata* (prickly-skinned animals, in which class the Star-fishes are included). He gave a description, accompanied by beautiful figures, of the anatomy of the common five-rayed Star-fish—*Asterias rubens*—and amongst the tissues figured was the nervous system, a copy of which is appended (Fig. 361).

Fig. 361.

Nervous system of Asterias.

Here a white ring is distinctly seen surrounding the oral aperture, and distributing three branches to each of the five rays.

1064. He also described the vascular system in the following remarkable words: "The vessels which absorb the chyle from the digestive sac, terminate after a series of reticulate anastomoses, in a circular trunk, which likewise receives branches from the radiated cœca. The venous circle communicates by means of a dilated tube, regarded as a rudimental form of heart, with *an arterial circle surrounding the mouth, from which branches diverge to the rays*, and other parts of the body."

1065. Authority is not wanting to confirm the fact that the vascular system, so accurately described by Tiedemann, is the same structure which himself and others have mistaken for a nervous system.

1066. In the uninjected state of the animal, the vessels are filled with *white*, coagulated blood, and in roundness, fulness, color, and general appearance, accurately simulate nerves.

1067. From all that is known of the necessities of a nervous system, it appears to be quite improbable that any such condition exists in the animal kingdom as that alleged to belong to the Radiata.

1068. It is extremely difficult to understand a nervous system, consisting only of a series of simple chords—unprovided with a single nervous centre, or ganglion.

1069. Now a ganglion is a knot of nervous matter; a brain of a kind; a centre of reinforcement; and the probability is that no nervous system exists, without, at least, one ganglion. If this be true, the nervous system in the Radiata has yet to be discovered.

Nerves possess distinct functions: thus, a nerve of sensation has

no power to direct or organize motion; neither is a motor nerve endowed with sensation.

A nerve of *vision* cannot perform the function of smell, taste, hearing, or touch; neither can the nerves of one organ assume the function of the nerves delegated to another organ; each has its own duty to perform, preserves its individuality, and is so far distinct.

1070. A nerve and a ganglion, as will be hereafter seen, possess, each of them, a peculiar and definite structure, and the only way to be sure of their presence is to cut off a small portion, and examine it with the high power of a compound achromatic microscope.

1071. Plants assimilate food, continue their kind, and the lower orders of them are even endowed with locomotion; the Venus' Fly-trap, and the Sensitive Plant would seem to offer the indications of a nervous system; so far as is really known, the lower animals appear to occupy a similar position with plants.

1072. From the foregoing statement, it will be advisable to commence the inquiry into the nature and condition of the nervous system, and its mode of development, in the Articulate sub-kingdom, all the individuals included in this section being unmistakably endowed therewith.

LESSON LXXI.

NERVOUS SYSTEM IN THE ARTICULATA. ENTOZOA—ANNELLIDA.

1073. In the lowest animals of this sub-kingdom, the parasitic *Entozoa*, the nervous system is very imperfectly developed, and, from their position within the bodies of other animals, but little required.

1074. In the intestinal parasite *Strongylus gigas*, a slender nervous ring surrounds the beginning of the gullet, and a single chord is continued from its inferior part, and extends in a straight line along the middle of the ventral aspect to the opposite extremity of the body, where a slight swelling (ganglion) is formed, immediately anterior to the posterior part of the body, which is surrounded by a loop, analogous to that with which the nervous chord commenced. The abdominal nerve is situated internal to the longitudinal muscular fibres, and is easily distinguishable from them with the naked eye, by its whiter color, and the slender branches which it sends off on each side. These transverse twigs are given off at pretty regular intervals of about half a line, and may be traced round to nearly the opposite side of the body.

1075. In the *Ascarides*, a dorsal nervous chord is continued from the œsophageal ring, down the middle line of that aspect of the body corresponding to the ventral chord on the opposite aspect.

1076. The nervous system of the ANNELLIDA, or red-blooded worms, as they are commonly called, presents a marked advance beyond its condition in the white-blooded parasitic worms; it consists of a double median central chord, or chain of small ganglions, extending from one end of the body to the other; the two chords diverge anteriorly to allow the passage of the œsophagus, and again unite above that tube to form a distinct, though small, bilobed cephalic ganglion.

1077. Most of the *Annellides* are provided with ocelli (eyes), and in many of them the head supports soft cylindrical tentacles (feelers), called (improperly) *antennæ:* they are obviously organs of touch, but differ from the antennæ of insects in the absence of joints.

FIG. 362.

Nervous system of the medicinal Leech.

1078. In this class the nervous system has reached a higher type and more constant plan of arrangement.

1079. It always commences by a symmetrical bilobed ganglion, which, both by its situation above the mouth and the parts which it supplies, merits the name of brain, which it has generally received.

1080. In the medicinal leech there are sent off from this ganglionic centre (Fig. 362, *a*), ten distinct optic nerves (*b*, *b*), besides many smaller filaments to the integument and other parts of the head; each optic nerve or filament terminates by expanding upon the base of a black eye-speck or ocellus, ten of which may be distinguished by the aid of a lens of moderate magnifying power, dotting, as it were, at equal distances, the upper margin of the expanded suctorial lip.

1081. The principal nerves which arise from the brain of the leech are what may be called analogically the crura, which diverge as they descend to embrace the œsophagus, and are often called the œsophageal chords; they then converge and reunite to join the large

sub-œsophageal ganglion (*c*). From this ganglion the muscles of the three serrated jaws, as well as the principal muscles of the oral (mouth) sucker, derive their nervous influence. Those who have watched the vigorous workings of this part in a hungry leech, beginning its feast, will not be surprised at the great development of the nervous centre of the suctorial and maxillary mechanism.

1082. Two chords, in such close apposition as to seem a single nervous band, are continued from the sub-œsophageal ganglion (*sub*, under, beneath) along the middle of the under part of the abdomen, attached to the ventral (*ventre*, belly) integument, and enclosed, as it were, by the great ventral vein. Twenty-one equidistant ganglions are developed upon these chords, which distribute their filaments to the adjoining segments by two diverging trunks on each side. The segments indicated by the external circular indentations of the integument are much more numerous than the ganglions. A simple nervous filament extending from the œsophageal ganglion along the dorsal aspect of the alimentary canal, has also been detected in the leech, and this forms the first trace of a distinct sympathetic nerve as yet seen in the animal kingdom.

1083. In the earth-worm (angle-worm) the brain or supra-œsophageal ganglion (*supra*, above) consists of two lateral lobes, which send off small nerves to the proboscis, and the two large connecting cords to the sub-œsophageal ganglion. The two ventral nervous trunks are more distinct from each other than in the leech, but the ganglions are relatively smaller and more numerous, corresponding in number with the segments of the body.

1084. In the *Nereis*, a marine worm, some species of which grow to the extent of two feet in length, the abdominal ganglions are more distinctly bilobed than in the earth-worm, and the supra-œsophageal ganglion is relatively larger, having to furnish nerves to both antennæ and ocelli. The pairs of ganglions developed upon the ventral chord correspond with the segments of the body in number, and are very close together.

1085. In the species which attains the great length indicated, *Eunice gigantea*, the nervous system consists of upwards of 1,000 ganglia.

In the Epizoa, the nervous system of Actheres percarum (Fig. 204) possesses a single cephalic ganglion, placed on the ventral surface, from which are distributed two principal chords (*g*, *g*), extending along the under surface of the body.

LESSON LXXII.

NERVOUS SYSTEM OF CIRRIPEDIA, AND MYRIOPODA.

1086. In the *Cirripedia* (*cirrus*, a curl; *pes*, a foot), commonly called Barnacles, or Acorn-shells, the nervous system is very simple.

1087. In the *Lepas vitrea* the œsophagus is surrounded by a white oval ring, at the sides of which are placed the small ganglions which supply the first pair of feet. The ring is completed below by the ganglions of the second pair of feet. The fifth and sixth pairs of ganglions are approximated to each other; there is no cerebral ganglion, but filaments are given off from the supra-œsophageal loop to the peduncle and sides of the head (see Fig. 363). Two of these branches pass to a small ganglion on either side, near the stomach, from which the digestive organs are supplied; the tubular extensile tail receives the last two pairs of nerves. The neurolemma (nerve sheath) is stained by a dark brown pigment in the Lepas vitrea.

FIG. 363.

Nervous system, Lepas vitrea (glassy).
a, Nervous ring, surrounding the œsophagus.
b, *c*, Parallel nervous abdominal chords.
b, *c*, *d*, *e*, *f*, Ganglia, supplying nerves to the curled feet.

1088. The class *Myriapoda* (many feet) contains the *Wood-lice*, *Iulidæ* (for which there is no common name), and *Centipedes* (hundred legs). Both these latter animals are found at the roots of trees; the Iulus is about an inch in length (in this country), the body very round, covered by a brittle, black, shining skeleton; its legs numerous, having two pairs on each segment of the body, and remarkably short. Some species, if touched, throw themselves on their side, and curl into a close ring.

1089. In these animals the condition of the nervous system is of much general interest. In them the corresponding ganglions of the abdominal chords are much less conspicuous than in the earth-worms, and the whole central axis of the nervous system, continued from the brain, is almost as devoid of partial swellings as the spinal chord of the apodal (without feet) vertebrates.

1090. A figure of the brain and chief distribution of the nerves, from an original preparation of Iulus, is shown at Fig. 364.

1091. The cephalic ganglion (*a*) of the Iulus, is transversely

elongated, and obscurely divided by a slight median indentation into two side-lobes; its upper and latter extremities are prolonged outwards into the optic lobes (*c*, *c*), which resolve themselves half-way towards the compound eye into a plexus of filaments (optic nerves) for its several divisions. Two separate antennal nerves, conjectured by Straus Durcheim to be motory and sensory (*d*, *d*), are sent off on each side below and in front of the optic nerves to the short, seven

FIG. 364.

Brain and principal nerves of Iulus.

jointed antennæ. On each side, also, but below the antennal nerves, arise the two nerves (*b*), united together by an anastomosing branch, which supply the mandibles.

1092. The thick œsophageal chords (*g*) are continued from the posterior and inferior angles of the brain; and, though apparently simple, consist essentially of two chords, which become separate at the lower part of the pharynx; the anterior chord girts the pharynx by a transversely oval ring, formed by the confluence with its fellow; the posterior and normal columns converge, at an acute angle backwards, blend together, and expand into the commencement of the abdominal nervous trunk; thus enclosing the œsophagus by a second and looser collar.

1093. The stomato-gastric, or sympathetic nerves (*f*), which arise from the posterior part of the brain, immediately form a third slender ring (*e*) about the œsophagus, from the middle of the upper part of which the trunk of the sympathetic system is continued a short way back upon the stomach, when it divides; the two divisions diverge at an angle of 45°, bend abruptly backwards, and run parallel with each other along the dorso-lateral parts of the wide and straight alimentary canal.

1094. Two large nerves (*h*) are sent forwards from the beginning of the thick sub-œsophageal or ventral chord (*i*), to supply the max-

illæ, which form the under lip; the nerves of the two single pairs of feet, belonging to the thoracic segments, next arise, and afterwards the more numerous minute nerves to the little feet, which, by their articulation to the segments in double pairs, indicate such segments to be merely a confluence of two segments. The simplicity of the abdominal chords corresponds with the close approximation and great numbers of the organs from which they receive impressions, and to which they transmit stimuli.

FIG. 365.

Portion of nervous system, Polydesmus maculatus.

1095. In the Polydesmus maculatus (*spotted*), (Fig. 365), the segments are fewer and larger than in the Iulus, and their lateral margins are produced; each, however, with the exception of the first three, which answer to the thorax in insects, supports two pairs of legs—but these are longer than in the Iulus.

1096. The abdominal nervous chords show as little trace of their median separation as in the Iuli, swelling into two slight enlargements (*a*, *a*) opposite each of the abdominal segments; two nerves are sent off from either side of each enlargement, and the anterior of these four pairs of nerves is directed at an acute angle forwards and outwards to the stigmata; it is doubtful, however, if these be nerves—analogy seems to indicate that they are arteries; the remaining pairs supply the muscles of the segment, and the legs, and are of equal size.

1097. In the Centipede (Scolopendra), a series of equal and equidistant ganglia is developed upon the ventral surface of the two abdominal chords. Only in the first and last of the abdominal ganglions can any modification of size be detected. The anterior or sub-œsophageal ganglion is larger than the rest, having to supply the modified legs which perform the function of jaws and underlip; the chords diverging as they escape on each side of the œsophagus, enclose it by uniting with the large bilobed brain above. The nerves from this part (the brain) supply the large antennæ and the aggregated ocelli; in other words, the organs of special sense.

1098. Even in animals so low in the scale of being as the class *Myriapoda*, we find the full recognition of the leading physiological divisions of a nervous system in the higher animals.

1099. Thus the supra-œsophageal ganglion or brain in these creatures, so far corresponds with the cerebrum of Man, that it is subservient to the functions of the special organs of sense, and is the

centre whence voluntary impulse may be directed along the non-ganglionic tracts of the nervous axis, and to which ordinary sensation may be transferred by similarly uninterrupted nervous filaments. So, too, we find the function of the cerebellum simulated by the large sub-œsophageal mass, which originating the nerves analogous to the fifth pair in man, and the higher mammalia, for the masticating organs and other parts of the head, may be regarded as analogous to the base of the brain.

1100. The stomato-gastric (sympathetic) nerves, complete this complicated system.

LESSON LXXIII.

NERVOUS SYSTEM IN CRUSTACEA.

1101. In the numerous and diversified class of *Crustacea*, every condition of the nervous system is met with, from that of the lowest Annellide, or the earliest larval state, where scarcely a filament is yet perceptible in the place of the nervous columns, to that concentration of the nervous ganglia around the œsophagus, which connects the highest Articulata with the Mollusca.

1102. The supra-œsophageal ganglia (*brain*) are generally larger than those of Arachnida, and smaller than those of Insects; they are, for the most part, united into a single cerebral ganglion, devoted chiefly to the large organs of the senses, and their nerves unite with the sympathetic, as in Insects.

1103. The ganglia of the cephalo-thorax (head-chest, which in these animals is soldered into one piece) vary much in their number, magnitude, and degree of approximation, according to the form of that part of the trunk, and the size of the several pairs of legs.

1104. Many of the lower Crustacea have the segments nearly equally developed from the anterior to the posterior extremity of the trunk, and this equal development is seen also in the nervous columns and ganglia of these segments, as shown in the subjoined figure of the nervous system of *Talitrus locusta*, or Sand-hopper, so common on the sea-shore (Fig. 366).

1105. The slender longitudinal columns, and the minute ganglia along their course, here remain distinctly separated from each other by a small space on the median plain; the ganglia are nearly of the same size from the first pair (*a*), above the œsophagus (*b*), to the caudal pair (*c*), and the pairs are almost equidistant along the whole

trunk, in a longitudinal direction.

FIG. 366.

Nervous system of Sand-hopper. *a*, Cephalic ganglia; *b*, Œsophagus; *c*, Caudal ganglia.

FIG. 367.

Nervous system of the Cymothoa.

1106. The same form of the nervous columns is seen in the highest Crustacea, while yet in their embryo condition in the ovum. In the short and broad trunk of the *Cymothoa*, where the legs are still equally developed along the sides of the body, the nervous columns (Fig. 367) have already approximated to touch each other on the median plane, and the ganglia on the two sides have coalesced to form a single chain along the middle of the abdominal surface of the body. The ganglia are still nearly equidistant, and equally developed along the columns; but where the minute posterior segments occur, the ganglia are closer together and smaller in size. The transverse concentration of the columns and ganglia towards the median plain, thus seen in the lowest Crustacea, is succeeded in higher species by a longitudinal movement of the nervous matter, directed, as we have seen in inferior classes of Articulata, chiefly to two points of the body, the head and the thorax, from which the largest and most important appendices of the body, whether for sensation, mastication, or progressive motion, are developed.

FIG. 368.

Nervous system of the Lobster.

1107. In the long-tailed Crustacea, as the Lobster (*Astacus marinus*), Cray-fish (*Astacus fluviatilis*), not only is the sympathetic system of nerves derived from the lateral ganglia of the stomach, but the ganglia and columns have coalesced and met transversely along the whole body; in the region of the thorax, from which the five pairs of large extremities are developed, the ganglia have enlarged in size above those of the post-abdomen, and considerably approximated to each other in a longitudinal direction (Fig. 368).

In the higher Articulata the segments first coalesce on the anterior and posterior portions of the trunk, and hence the enlarged form presented by their cephalic and caudal ganglia, independent of the great size often attained by the appendices developed from the terminal parts of the body.

The cephalic ganglion is shown at *a*, and this, together with the ganglia which succeed it, down to *b*, is of larger size than the abdominal ganglia, with the exception of the last (*c*),) which in this form of the nervous system always attains increased size.

1108. The most concentrated form of the nervous system met with in the Crustacea, is that found in the short and broad trunks of the *Crabs* (Fig. 369), where all the symmetrical ganglia of the columns are collected into two masses, the one in the head, and the other in the centre of the cephalo-thorax; the sympathetic nerves are confined to a nervous band around the wide œsophagus. The supra-œsophageal ganglion, or brain, is comparatively small in the Crabs, from the smallness of the cephalic appendices, which it supplies with nerves.

FIG. 369.

Nervous system, Crab.

1109. The infra-œsophageal mass is of great size, consisting of the whole chain of ganglia, which was originally extended along the body behind the œsophagus, fused into one mass. It sends out numerous branches to the surrounding viscera, and to the five pairs of legs which radiate from around that point, and the columns are prolonged backwards, ramifying along the short slender post-abdomen, as a simple nervous chord.

LESSON LXXIV.

NERVOUS SYSTEM IN INSECTS.

1110. In Insects the nervous system differs chiefly from that in the *Myriopoda* in having its primary divisions more definitely developed, and in manifesting degrees of concentration corresponding with the increase of bulk and strength in particular parts of the trunk,

and in the locomotive organs appended thereto. Most Insects, however, commence their career as worms; the high form which they are ultimately destined to attain in the articulate series, is at first marked by the guise of a red-blooded worm.

1111. The larvæ, which present larger and more perfect segments, most of which are provided with legs or prolegs, have a ganglionic centre for each segment, and intermediate chords.

1112. This worm-like type of the nervous system can be seen in any caterpillar, and an illustration is given (Fig. 370) of the nervous system of the larva of the Goat Moth, *Cossus ligniperda*—immortalized by the wonderful dissections of Lyonnet, and the engravings, by his own hand, which gave effect to his labors as an Entomotist (one who dissects insects).

The abdominal nervous columns of insects have been regarded by Lyonnet, Straus, Dufour, and Chiaje, no less than by modern authorities, as analogous to the brain and spinal chord of vertebrated animals. There are at first thirteen pairs of approximated ganglia, corresponding with the original segments, and extending along the middle of the ventral surface of the body, and the œsophagus passes downwards, perforating the connecting nervous columns between the first and second pairs of ganglia; in other words, the œsophagus in insects passes through *the centre of the divided brain;* the *first* pair of ganglia, therefore, are *supra*-œsophageal (*above* the œsophagus), or cephalic, and all the succeeding ganglia of the columns are beneath the alimentary canal.

1113. The ganglia, at first like those of the worm and centipede, are nearly at equal distances, and of equal size, like the segments themselves of the young caterpillar. The columns and ganglia, originally separate (see Fig. 366, of the nervous system of the Sandhopper, which, although a lowly crustacean, illustrates this point,) on the two sides, early approximate transversely, and unite, and a slow movement of the ganglionic matter is at length observed in a longitudinal direction. These *transverse* and *longitudinal* movements of the nervous matter proceed to a very variable extent, according to the degree of metamorphosis from the larva condition, to which the individual is subjected in the various adult forms of this class. In insects, as in the *Myriopods*, the first and second pairs of ganglia are contained within the head, and constitute, together, the brain; the succeeding pairs are generally placed near the anterior limits of the segments to which they belong. The third pair of ganglia placed in the *prothorax* (first division of the chest) appear to be

generally smaller than the fourth; and the fifth, in the *mesothorax* (middle division of the chest), smaller than the sixth, contained in the *metathorax* (last division of the chest).

1114. The ganglia contained in the abdomen, like the segments of that part of the body, are generally the least altered by development from their primitive condition; in the *Coleopterous* insects (*Beetles*), however, the majority of them become obliterated in the progress of development, and the like occurs in many of the *Hemiptera* (Tree bugs). The last pair of ganglia are generally the first to advance forward and unite with the penultimate pair in the larva state.

1115. In the larva of a *Lepidopterous* insect (butterfly), the columns are lengthened, and the cephalic ganglia widely separated to allow the œsophagus to pass between them. The first of these ganglia, equivalent to the cerebrum of man, gives off the nerves for the supply of organs of *special* sense; these amount in caterpillars to *eight* pairs, in addition to the nerves which connect the *upper* with the lower part of the brain; the latter are called the *crura*. They likewise give off filaments to the small lateral ganglia (*c*) of the head, and to the commencement of the sympathetic series of ganglia (Fig. 370).

1116. Between all the succeeding pairs of ganglia, a solitary branch is seen coming through the loop formed by the division of the chords in the upper part of the figure; it divides into two branches, one passing to the orifice of the spiracle (breathing mouth) on the right side, and the other to the like organ, on the left. These branches invariably come off *above* the ganglia.

1117. Ninety years ago these structures were described by Lyonnet, as *motor* nerves, and the fact that their ramification was distributed to the muscles employed in respiration, favored this opinion. The opinions of Lyonnet were adopted and maintained by all succeeding authorities, but

1118. In the *Limulus polyphemus*, or King Crab, found in considerable numbers on the Jersey coast, the heart agrees with the figures given of the heart in Insects, *i. e.*, a straight vessel, from the anterior chamber, terminating in *three vessels*, two of which are lateral, and descend down to the nervous ring surrounding the œsophagus, the middle one being lost in the head: thence a branch passes along the dorsal surface of the ganglionic ventral chord, invariably giving off branches in front of each ganglion,—in fact the motor—and as some authors have designated it, *respiratory tract* of Insects.

If a small pipe be tied in the heart, and injection (size colored with vermilion) be thrown in, these so-called *nerves* will be demonstrated as *arteries*. If the same experiment be made from the heart (dorsal vessel) of a caterpillar, the like results will be obtained, and thus establish the true character of this structure in *Insects*, *Myriopods*, and the lower *Crustacea*, and demonstrate beyond all doubt that the so-called motor, and respiratory nerves, in all these animals, are a system of arteries. Being always filled, however, with *white, coagulated blood*, in death, the main trunk from which the branches are distributed lying upon the upper surface of the gangliated nervous chord, and exceedingly minute and attenuated in structure, they much more resemble nerves than arteries.

LESSON LXXV.

NERVOUS SYSTEM OF INSECTS, CONTINUED.

1119. The individuals composing the articulate sub-kingdom have their bodies divided into a series of more or less distinct *rings*, or *segments*, arranged in a linear series. This disposition is more apparent in those animals which exhibit lowly organization, that is to say, the *Worms*, *Myriopods*, and the *larval* condition of Insects.

1120. Carefully examined, it will be seen that in structure, internally, these segments present merely a repetition of parts, and this statement is equally true of the *nervous system*.

1121. In the centre of each segment of a *Centipede*, or a *caterpillar*, a nerve-knot or ganglion is invariably found; from this nervous centre the muscles of the segment obtain their supply of nervous impulse; the only exception to this rule is in regard to the superior portion of the brain—the supra-œsophageal ganglion—where we find the nerves solely distributed to the organs of special sense, and to the development of the *frontal* ganglion, from whence the sympathetic nerves arise. An illustration is given of the nervous system of the caterpillar of the Goat Moth, *Cossus ligniperda* (Fig. 370), copied from an original preparation.

1122. The bilobed ganglion, having a long transverse diameter (*a*), is the supra-œsophageal ganglion, or brain; the nerves dis-

FIG. 370.

Nervous system of Cossus ligniperda.

tributed from this portion of the nervous system are given to the organs of vision, feeling, taste; supplying all the organs devoted to special sense. Two branches arise from the anterior (front) portion which terminate in a small ganglion, from which a delicate nerve arises.

1123. This nerve *returns*, as it were, and was hence called by its discoverer, Lyonnet, the *nervus recurrens*, or *recurrent* nerve; it is distributed upon the œsophagus and stomach, where it terminates: this is the stomato-gastric (mouth stomach), or sympathetic nerve.

1124. The superior portion of the brain is connected with the inferior or sub-œsophageal ganglion (*b*), by a pair of nervous chords, widely separated, to admit the œsophagus (*d*), or gullet, which passes through this divided brain. The great necessity for such an arrangement of the nervous system in any animal, by which it is rendered imperative that the alimentary canal should pass through the centre of the brain, is, that the superior portion of it (the brain) must necessarily be always placed in the vertex, to supply the organs of special sense with nerves. The muscles of the jaws, &c., receive their supply of nerves from the inferior surface of the brain, which, by the contrivance re-

sorted to, is on the same plane; and lastly, the protection of the bulk of the nervous system requires it to be transferred from the dorsal to the ventral surface.

1125. From its function of distributing the nerves of sense, therefore, the brain requires to be placed in the superior part of the head, adjacent to the organs which it is destined to supply with nerves. For a like reason (proximity to the structures to be supplied with nerves), and, as stated in the preceding paragraph, for superior protection, the remainder of the nervous system is placed upon the ventral surface of the body, and this could only be accomplished by dividing the brain, and transmitting the alimentary canal through the space thus formed.

1126. All the nerves which arise from the base of the brain are *motor* in their function, and they are, therefore, distributed to the muscles of the jaws. Nerves arise from the lower surface of the sub-œsophageal ganglion, one on each side, which terminate in a minute ganglion (*c*) called *lateral* ganglia; from these a few delicate nervous twigs arise, which are distributed to the muscles of the throat.

1127. The first thoracic ganglion (*e*) is near the base of the brain; its nerves are distributed to the muscles of the segment to which it belongs.

1128. The second (*f*) and third (*h*) thoracic ganglia are remarkable for their increased size, and the chords connecting them for their great divergence. Between the loops thus formed a branch is seen descending from the inferior surface of the ganglia respectively (*g*, *g*), and giving off a branch right and left.

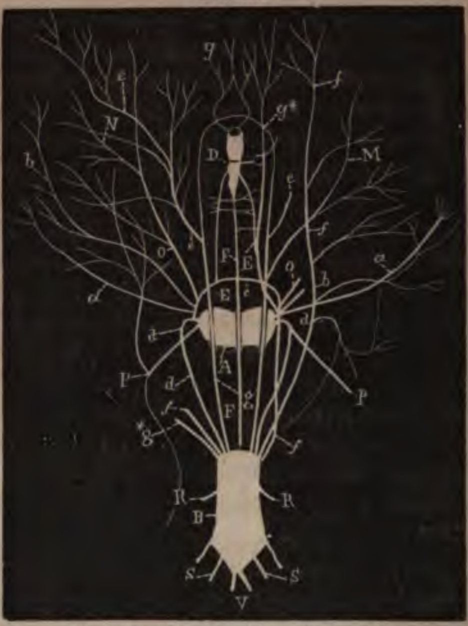
1129. This structure is continued throughout the entire nervous system, the branches being invariably given off *above* the ganglions. By careful dissection their ultimate branches may be traced to the muscles of the respiratory organs, and hence they have been thought to constitute a distinct respiratory tract, combining a motor function. They are not such, however, but simply a system of arteries, and these are the vessels which have been injected from the heart in Insects, and in the Limulus, as already described.

1130. The remainder of the nervous system is simply a repetition of what has been already described, until we reach the terminal, enlarged ganglion (*k*). This is called the *caudal* (tail) ganglion, and is formed by the junction of the 11th and 12th ganglions.

1131. The most important portion of the nervous system of any animal is the *brain*, and we present a much magnified view of that

organ as it appears in the same Caterpillar (Fig. 371), and the following is the description of the nerves proceeding from it, and the organs to which they are distributed :

FIG. 371.



Brain of a Caterpillar (Cossus ligniperda).

A. Cerebrum, superior portion of the brain.
B. Cerebellum, inferior portion of the brain.
a, *a*. Nerves of the eyes.
b, *b*. Of the antennæ.
c. Cord passing around the œsophagus, proceeding from the cerebrum.
d, *d*. Cord connecting the cerebrum and cerebellum.
e, *e*. Nerves of the mandibles (upper jaws).
f, *f*. Nerves of the maxillæ (under jaws).
g, *g*. Second connecting nerve of the under lip, of which the nerve of the mandible is a branch.
*g**, *g**. First nerves of the under lip, which give off a branch, M, to the muscles of the lower jaws. (The branches of the second nerve of the lip, *g*, *g*, give off a branch for a muscle, N.)
O, O. Nerves of the muscles of the upper jaws and antennæ.
P, P. Nerves of the muscles of the upper jaws.
R. R. Nerves that distribute themselves at the posterior portion of the skull.
S. S. Nerves of the muscles of the neck, which pass into the thorax (chest).
V, V. Connecting cords of the cerebellum and first thoracic ganglion.
D. The frontal ganglion, formed by the two branches, E, E, whence the sympathetic nerve, F, originates.

1132. It would be easy to present a further and more enlarged view of the Cerebrum, chiefly for the more perfect demonstration of those parts which are somewhat obscure, from the complexity of the preceding figure, but want of space forbids it.

1133. It has been shown that in the larval condition of an insect

the ganglia are remarkably symmetrical, with the exception of the brain, each having to supply precisely the same nerves to the like organic structures.

In the perfect insect, however, it is found that great absorption has occurred of ganglions no longer required, and a corresponding deposition of nervous matter, to increase the size of certain ganglia whose influence is imperative. In illustration of this fact, the nervous system (in situ, Fig. 372), of the natural size, is offered from the *Blatta Americana* (American Cockroach). Here the abdominal ganglia (*d*) are minimized, and the *thoracic* ganglia are largely but unequally developed.

FIG. 372.

Nervous system of the natural size of B. Americana.

1134. From these nervous centres it is that the large and powerful superior (wings) and inferior locomotive organs (legs) obtain the nervous influence necessary to the performance of their functions. The first thoracic ganglion (*a*) having only to distribute nerves to the *smallest* pair of legs, is the least in size; the second thoracic ganglion (*b*) has to supply not only the intermediate pair of legs, which are larger, but the *superior* organs, which, whilst they afford protection to the true wings, are also engaged to a limited extent in the action of flight.

The third, and last thoracic ganglion (*c*), is required to give impulsion to the last and very powerful legs, at the same time that it does the like to the real organs of flight—the wings. Here, therefore, we see a greatly increased size in the nervous centre, especially devoted to this function. The abdominal ganglia (*d*) supply the muscles of the abdomen only, and are minute and uniform in size.

LESSON LXXVI.

NERVOUS SYSTEM IN ARACHNIDA.

1135. The nervous system in one class of articulate animals yet remains to be examined, the *Arachnida*. The class contains the *Mites*, *Scorpions*, and *Spiders*, and has usually been placed by naturalists below the *Crustacea*, and between it and Insects.

1136. These animals present a more concentrated form of the nervous system and of the heart than the animals previously examined; the larger species likewise offer a higher condition of the respiratory system, which is less diffused than in Insects, and in some consists only of air sacs, or lungs.

1137. But the most essential mark of the superiority of the Arachnida is the course of their development. The spider undergoes no metamorphoses comparable with those of insects. It is at no period of its development an apodal (legless) worm.

1138. The head is always, in the Arachnida, soldered to the chest, which thus forms the cephalo-thorax before alluded to; it is also deprived of antennæ.

1139. They all have *four pairs of legs*, which of itself forms an important characteristic; thus, an Insect is divisible into *three* chief portions of its body, head, chest, and abdomen, to which neither more nor less than *three* pairs of legs are superadded.

1140. The *Crustacea*, like the *Arachnida*, are divided into only *two* portions, head-chest and abdomen, the legs being *never less than five pairs*, and frequently a greater number.

1141. The majority, but not all of these animals, are, like the Insects, air-breathing; to this rule there are, however, some exceptions amongst the *Mites*, and certain Spiders.

1142. The *Mites*, as their common name imports, are exceedingly minute; many of them, too, are parasitic.

1143. Man is the victim of two species of them, one the *Demodex folliculorum* (Figs. 245–'6–'7), being by far the most minute that has yet been discovered, and the other is the Acarus scabiæi, or the itch animal.

1144. That most loathsome of all diseases which afflicts humanity, *the itch*, and the *mange* in dogs, are both caused by the presence of a microscopical mite; the species, however, in man and the dog, differ.

1145. The animal which afflicts the human family is known as the *Acarus scabiæi*, or by its more modern name of *Sarcoptes galei*. An illustration of this animal is given (Fig. 248).

1146. This disease never occurs in any but *very dirty people;* through unpardonable neglect of washing the skin, the accumulation of matter constantly being thrown off from its surface, produces disease, and this disgusting parasite, when all other means are neglected, comes, as a physician, to effect a cure; this process is, however, generally a lengthy one, until the aid of a physician of another kind be invoked.

1147. From their remarkable minuteness, we have no direct testimony in relation to the condition of the nervous system in the *Mites*; but in the Scorpion we find the principal masses or ganglions concentrated around the œsophagus in the cephalo-thorax.

1148. From the small bilobed cephalic mass are sent upwards the optic filaments, in front the nerves of the large forcipated claws, and, backwards, the sympathetic nerves; the sub-œsophageal ganglionic columns distribute nerves to the great under jaws, and to the four pairs of thoracic legs; two slender continuations of the double columns are continued along the jointed abdomen, or tail, and seven small ganglions are developed upon them, from which nervous filaments are distributed to the surrounding parts.

1149. In Spiders the central masses of the nervous system are wholly, or in great part, concentrated in the cephalo-thorax. The brain is a bilobed ganglion (Fig. 373, *c*), sending forwards and upwards the optic nerves (*o*) from its anterior angles, and below these, the two large nerves (*m*) to the mandibles; a short and thick collar encloses the narrow gullet, and expands into a second very considerable stellate or radiated ganglion (*s*) situated below the stomach; it sends off five principal nerves on each side: the first (*p*), to the feelers of the under jaw; the second (*l*), to the feelers of the under lip; the three posterior nerves supply the remaining legs.

Fig. 373.

Nervous system of Spider.

LESSON LXXVII.

NERVOUS SYSTEM IN THE MOLLUSCA.

1150. The nervous system in these animals is arranged on a totally different plan from what we have seen in the Articulata.

1151. In contradistinction to the uniform system of arrangement of the nervous system, so constantly displayed in the latter subkingdom, the Mollusca are remarkable for the unsymmetrical form of its development. The cephalic ganglia, when two in number, are

separated by an interval of space, and connected by a nervous chord which passes *behind* the œsophagus.

1152. In the Articulata we found the alimentary canal invariably transmitted *through* a nervous ring which surrounded it; thence the remaining ganglia were periodically developed at stated intervals upon a double nervous chord, extending in the direction of the long axis of the body.

1153. In the Mollusca the ganglia are always connected by a *single*, not a *double*, chord; moreover, the number and disposition of all except the cephalic ganglions, is extremely variable, and of these only one is met with in the lowest animals of the class.

1154. Again: in the Articulata, the advance in the development of the nervous system is most conspicuous in the organs peculiar to animal life, and is chiefly manifested in the powers of locomotion, and in the instincts which are so various and wonderful in the class of insects.

1155. In the Mollusca, on the contrary, the organizing energies seem to have been chiefly expended in the perfection of the nutrimental series of organs, and of those concerned in the immediate preservation of the individual and of the species.

1156. The Mollusca are so called on account of the uniformly soft, unjointed nature of their external integument.

1157. In a large number of the lower organized Mollusca, there is no head, and no nervous centre is needed above the gullet for the reception of the impressions received by special organs of sense. All other Mollusca are provided with a head, which generally supports feelers, or soft tentacula, eyes, and a mouth armed with jaws.

1158. Amongst the lowest of the molluscous animals, is the class *Tunicata;* in these creatures the nervous system is more rudimentary than we have described it; only *one* ganglion has yet been discovered, from which the filamentous nervous system is distributed throughout the body.

In Cynthia pupa (Fig. 253) the nervous system consists of a single ganglion (*n*) connected to a nervous chord which surrounds the respiratory orifice (*a*). Fine nervous twigs are distributed to the large vibratile organs, and a chord (*d*), of more than ordinary dimensions, commences at *e*, and passes down, without distributing branches, to the bottom of the sac, where it is lost.

1159. The second order of the class *Tunicata*, includes the *Salpians*, which float in the open sea, and are characterized by their transparent elastic outer tunic, which is elongated, compressed, and open at both extremities.

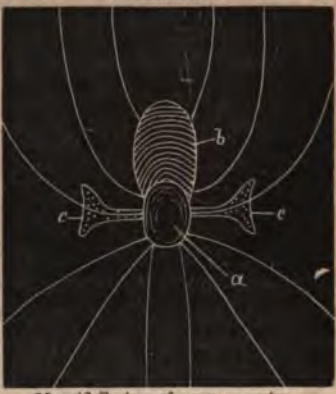
1160. The muscular fibres of the cloak, or mantle, are arranged in flattened bands (Fig. 374, *e*, *e*). The mouth and stomach, the liver and the heart, are aggregated in a small mass near the posterior aperture of the tunic (*d*); the intestine (*c*) extends towards the opposite aperture (*a*), and terminates in the common cavity of the mantle. The brain and nervous system are seen at *f*.

1161. In *Salpa polycratica* (Fig. 374), the nervous system will be found beautifully developed, of which an enlarged view is given in

FIG. 374.

Salpa polycratica.

FIG. 375.



Magnified view of nervous system, S. polycratica.

Fig. 375. The word *Salpa* is Greek, and means a small fish; *polycratica—poly*, much; *cratica*, from *kratos*, strength.

By reference to the figure it will be seen that the nervous system consists of *two lobes*, or ganglia, not separated by an interval of space, but lying one upon the other. All the nerves are, without any exception, distributed from the larger lobe, which is the equivalent of the base of the brain, or infra-œsophageal ganglion (*b*), and are distributed to all parts of the body; the analogue of the supra-œsophageal ganglion (*a*) sends off two branches at right angles, which terminate in expanded lobes (*c*, *c*). Nerves are not given off from this latter lobe, simply because the creature is destitute of organs of

special sense, and this portion of the brain may be considered as *rudimentary.* So, too, the transverse lobes (*c*, *c*), which form, in all probability, the elements of organs hereafter destined to become *Optic lobes.* It is curious, however, to observe that whilst the portion assumed to be the supra-œsophageal ganglion is uniformly very dark in color, perhaps caused by a dense aggregation of ganglion corpuscles, the lateral lobes are conspicuous for the great number of these *corpuscles* they contain, which may be distinctly seen in the figure.

1162. From this remarkable condition of the nervous system, it appears highly probable that the Salpa, as such, is simply in a *transition state*, and it may eventually happen that, when we have cultivated a more perfect acquaintance with it, it will be found to progress to another form, and a higher state of development.

LESSON LXXVIII.

NERVOUS SYSTEM IN THE BRACHIOPODA.

1163. In the Brachiopods (*brachion*, an arm; *pous*, a foot), a class of Mollusca which anciently existed to an immense extent during the *secondary* period, and are found most abundantly fossilized, but now restricted to three Genera, *i. e.*, *Lingula*, *Orbicula*, and *Terebratula*, we have animals of great physiological interest.

1164. In *Terebratula Australis*, only one ganglion is found, as in the Tunicata, from whence the nerves are distributed to the vascular mantle, the strongly ciliated arms (from which the class obtains its name), and to all parts of the body. It is very difficult to find this ganglion, and for a long time it eluded detection; it is beautifully displayed, however, in a preparation, a copy of which is represented at Fig. 377, *a*.

1165. The Terebratula lives at a great depth in the ocean—not less than from *sixty* to *ninety fathoms ;* for security, it attaches itself to submerged rocks, by means of a strong pedicle which projects through a hole in a beak-shaped prolongation of one of the valves. All the individuals of this class are bivalves.

1166. The dorsal layer of the mantle (Fig. 376) presents a very interesting spectacle. At the upper surface two pairs of very short, powerful muscles (*a*, *b*) may be seen, for the purpose of closing the valves. These muscles are somewhat triangular in shape, and terminate each in a short, strong tendon, of great beauty, situate at

their summit. A large and very capacious vein (*c*, *c*) runs through each side of the mantle, which divides into a great number of smaller branches, distributed to the outer edge of the mantle. In the centre of each of these veins, an artery (*e*, *e*) is distributed, and ramifies everywhere upon their surface. In addition to the vascular system, nervous filaments (*f*) are extensively distributed; they are given to the muscles, and pass directly through the mantle to its edge. The

FIG. 376.

Dorsal mantle of Terebratula Australis.

sexes are distinct in Terebratula; thus the Ovarium, filled with eggs, is seen at *g*, and the external thickened margin of the mantle at *h*.

1167. Having to breathe under such an enormous weight and pressure of water, something more than the ordinary form of respiratory apparatus becomes essentially necessary.

1168. There are no special organs of respiration in these animals; that function appears to be performed by the singularly vascular mantle, but accessory thereto is, doubtless, the very powerful arms, with the no less powerful vibratile cilia. By their action, the surfaces of the mantle are kept constantly laved with water for respiration, and as the fluid always makes a circuit in one uniform direction in this, as in other bivalves, the food which is contained in it is conveyed to and appropriated by the mouth, which is abundantly supplied with its own vibratile organs for that purpose (Figs. 256 and 257, *a*, *a*).

1169. Each arm extends outwards, advances forwards, curves slightly inwards, and bends abruptly back upon itself, the two parts of the bend being connected together; then the stem again curves forward, and becomes united to the corresponding bend of the opposite arm, the conjoined extremities describing spiral convolutions turned towards the dorsal valve; the bent portions of the fringed arms are supported by slender and elastic calcareous processes. In all the Brachiopods, the stem which supports the brachial fringe is hollow.

1170. In the *Terebratulæ*, and *Orbiculæ*, the spiral terminations of the arms have their central canal surrounded by a double oblique series of muscular fibres; the canal is filled with fluid, and, by the contraction of the muscular fibres, the extremities are extended by the pressure of the contained fluid which is injected into them.

1171. The structure of the alimentary canal, and its accessory appendages, have been described in their proper place (p. 159).

1172. So, too, the organs of circulation, consisting, as some authors (Owen) have supposed, in a heart placed on either side of the alimentary canal, from whence the blood is distributed to all parts of the body, especially to the vascular mantle. The probability that these views are erroneous has been already stated (p. 158).

1173. In the nervous system of Terebratula, we find a nervous collar, with only one ganglionic enlargement, surrounding the œsophagus—the ganglion being placed above the latter (Fig. 377, *a*). Nervous filaments are distributed to the ciliated arms (*d*), the adductor muscles, and to the vascular lobes of the mantle (*b*, *b*).

1174. Two pairs of short, powerful muscles arise from each valve, some of which are lost in the opposite valve, and others lost in the pedicle.

1175. The pedicle is surrounded by an elastic yellow horny layer and a tubular prolongation of the mantle.

1176. The true history of these interesting animals has been given in the following beautiful and graphic language, by Prof. Owen: "Both the respiration and nutrition of such animals, which exist beneath such an amazing pressure as a column of ninety fathoms (540 feet!) of sea-water, are subjects suggestive of interesting reflections, and lead one to contemplate with less surprise the great strength and complexity of some of the minutest parts of the frame of these diminutive creatures. In the unbroken stillness which must pervade those abysses, their existence must depend upon their power of exciting a perpetual current around them, in order to dissipate the water already laden with their effete particles, and to bring within the reach

of their prehensile organs the animalcules adapted for their sustenance." The microscopical examination of the contents of the sto-

FIG. 377.

Nervous system, Terebratula Australis.
a. Ganglion. *b, b.* Nerves of the mantle. *c, c.* Veins. *d.* Nerves of the arms.

machs of numerous Terebratulæ, has uniformly disclosed to view myriads of well known minute siliceous forms erroneously ascribed by Ehrenberg to the animal kingdom.

LESSON LXXIX.

NERVOUS SYSTEM IN THE LAMELLIBRANCHIATA (*LAMELLA*, A PLATE; *BRAGCHIA*, GILLS).

1177. The relation of the contained soft parts to the bivalve shell of the Brachiopoda is such that, in the *Terebratula*, the perforated valve must be regarded as the inferior or central one, and the imperforate or shorter valve the dorsal one.

1178. In the *Lamellibranchiata* one valve is applied to the right and the other to the left side of the animal.

1179. The nervous system advances in a regularly proportional degree with the complexity of the general organization, and especially

with the muscular system; the ganglion upon the posterior adductor, which is most conspicuous in the *Oyster*, *Mussel*, *Pecten*, and other Bivalves, is the largest and most constant.

1180. It supplies the branchiæ with their nerves, and is called, therefore, the *branchial* ganglion; but it distributes an equal share of nerves to the posterior dorsal and anterior parts of the mantle.

1181. In the common Mussel (*Mytilus edulis*) the labial or cephalic ganglions may be distinguished by their rose color (when fresh) at the base of the labial processes (*a*, Fig. 378). They are connected by a short transverse nervous chord (*b*), which passes behind the mouth. From each of these ganglions two principal nerves are given off, one passing forwards to the anterior adductor (*q*), the other backwards along the base of the foot and the visceral mass to the posterior adductor (*g*, *g*). At a short distance from the cephalic ganglia this latter nervous chord (*g*, *g*) sends off a branch (*c*, *c*), which terminates in a ganglion at the base of the foot (*d*); as each of these branches ends in a ganglion, for the supply of nerves to the foot, they coalesce, and a bilobed pedal (*pes*, foot) ganglion is formed. The *cephalic* (*a*), *pedal* (*d*) and *branchial* (*h*) ganglions, constitute the important *centres* of the nervous system in this and other bivalves. The pedal ganglia distribute nerves in one direction to the retractors of the foot; in another to the substance of the foot (*f*) itself. The branchial ganglions (*h*, *h*) send off nerves, which are distributed principally to the breathing organs (*m*, *m*), and two large nerves which diverge as they pass over the adductor muscle (*j*, *j*), to proceed to the base of the tentacular processes guarding the posterior lobes of the mantle; these continue along the margin of each lobe of the mantle, until they meet and anastomose (join) with similar branches, which are continued over the *anterior* adductor muscles descending from the *cephalic* ganglions.

1182. The most remarkable fact demonstrated by the preparation of which a copy has been given, is the surprising and persistent connection of the ganglionic centres; throughout this nervous system it invariably occurs that a nerve which has its origin in one ganglion, terminates in another. By this means the cephalic ganglions are connected, and the *circuit* made perfect.

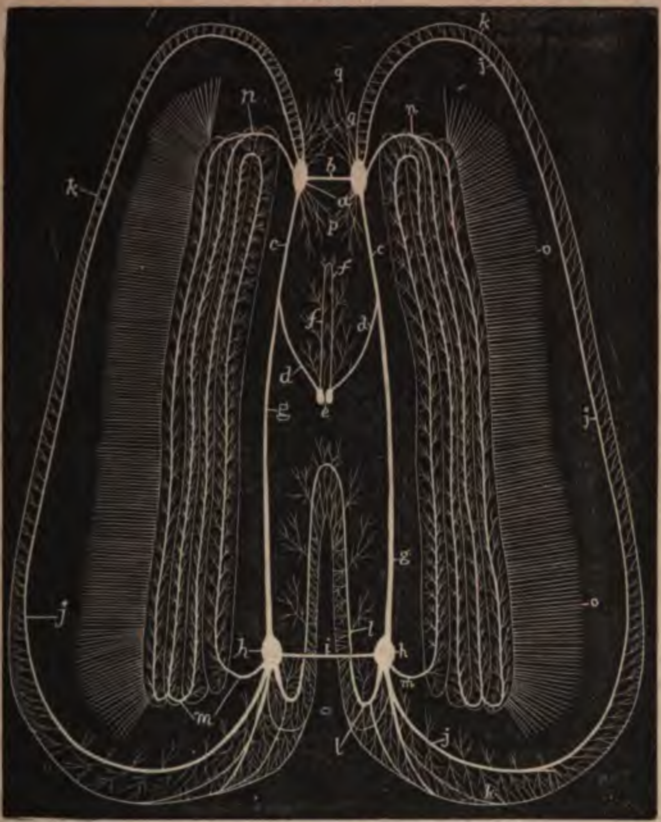
1183. The nerves (*c*, *c*), which arise from the cephalic ganglia respectively, terminate in *d*, *d*, the pedal ganglia, whilst these, in their turn, are connected by the looped nerves, *f*, *f*.

1184. The cephalic are connected with the branchial ganglia, through the medium of the dorsal chords, *g*, *g*; one branchial gan-

glion connects with its fellow, by the agency of the commissural nerve, *i*.

The demonstration of the figure is as follows:

FIG. 378.



Nervous system of Mytilus edulis (common Mussel).

a. Cephalic, or labial ganglia.
b. Commissure, or nervous chord, passing behind the œsophagus, uniting them.
c, *c*. Nerves, derived from the cephalic ganglia.
d, *d*. Their termination in ganglia at the base of the foot.
e. Bilobed pedal (*pes*, foot) ganglia.
f, *f*. Nerves from the pedal ganglia distributed to the foot.
g, *g*. Nerves which originate in the cephalic ganglia, and terminate in
h, *h*. The branchial ganglia.
i. Commissure, or nervous chord connecting branchial ganglia.
j, *j*. Branches from the branchial ganglia, which are distributed to the inner margin of the mantle.
k, *k*. Nerves derived from *j*, *j*, and the branchial ganglioa, and distributed to the outer margin of the mantle.
l, *l*. Branch from branchial ganglion, distributed to the posterior part of the mantle.
m, *m*. Nerves distributed to the gills, forming the *branchial plexus*.
n, *n*. Terminal nerves from the branchial plexus, ending in the cephalic ganglia.
o, *o*. The gills.
p. Sympathetic nerves, derived from the cephalic ganglia, and distributed to the stomach.
q. Nerves distributed to the anterior adductor muscle.

1185. The respiratory, or branchial nerves, have their origin in the branchial ganglions on either side; they ascend one lamella of the gills, giving off numerous minute branches, and forming plexuses; the main respiratory trunk then descends the next lamella, giving off its plexuses by the way; arrived at the lower portion, it again ascends, but prior to doing this it sends off a branch to the fourth and last lamella of the gills, when the main trunks ascend lovingly side by side, giving off their minute plexuses by the way, till they reach the summit. Here the fourth lamella gives off the (now attenuated) main nerve, which receives a branch from the third lamella, and continues its course till the circuit be completed in the cephalic ganglion.

1186. The pallial (*pallium*, a cloak or mantle) nerve, *j*, also originates in the branchial ganglion; we trace it throughout the circumference of the mantle, accompanied by its fellow, *k*, till we lose them both at the anterior portion of the body, in the *cephalic* ganglion.

1187. The post-pallial nerves (*l*, *l*) arise from the branchial ganglion on one side, and form a loop which terminates in the other; to end this surprising history it is only necessary to add that the sympathetic nerves are given off by one cephalic ganglion, and end in the other.

1188. Reasoning from the facts adduced, it would appear that the principle (so far as is known) firstly enunciated in a *Lamellibranchiate mollusc*, continues through the classes till it (probably) culminates in man; it is very far from reasonable that such an arrangement pertains to these creatures alone. Whenever our dissections of the nervous system of man and the higher animals become more perfect, it may result that the like connection of the great nervous centres is equally complete.

The *looping of terminal nerves* in man and the higher mammalia is well known, as witness the nerves in muscle, Fig. 352; this seems to be confirmatory of the principle here shown to exist, extensively, throughout the entire nervous system of an animal. Should such an arrangement be generally true, there would be no difficulty in understanding the phenomena of the reflex action of the nervous system, together with other and important phenomena in connection with peculiar nervous affections, to which poor humanity is prone. The series of preparations in which the foregoing facts are recorded, were dissected for the Hunterian Museum, where they still remain.

LESSON LXXX.

NERVOUS SYSTEM IN THE GASTEROPODA.

1189. The meaning of this word has already been given, and it will be at once apparent that its application is to the *slugs* and *snails*, whether inhabitants of the earth, fresh waters, or of the ocean, the whole of which progress upon their *belly-foot*.

1190. The majority, but not all, of these animals are *androgynous* (*anèr*, a man; *gunè*, a woman); both sexes are combined in the same individual.

1191. From the great power of locomotion possessed by this class, it is evident that the muscular system has acquired an increase of development as compared with the *Lamellibranchiata*, and, corresponding to this, is the increase in development of the nervous system, and the development of a brain.

1192. Thus we observe, in the lowest and least locomotive *Gasteropod*, a tendency in the nervous system to be aggregated at the forepart of the body, the cerebral ganglions rising more to the upper surface of the now well-developed head, and the branchial and pedal ganglions beginning to concentrate themselves about the mouth.

1193. In the slug and snail the principal centres of the nervous system are a supra-œsophageal and a sub-œsophageal ganglion, but the complex character of the latter and larger mass is indicated by the triple nervous chord, which completes on each side the collar round the alimentary tube. From the inferior mass the nerves radiate to the muscular foot, the soft and susceptible integument, and the circulating and respiratory organs. The upper ganglion gives off the large nerves of the tentacles and ocelli; it also communicates on each side by two minute filaments proceeding from its posterior and outer angles, with a small pair of sympathetic ganglions situated on the side of the œsophagus.

1194. In the *Bulla lignaria* (Fig. 379) there is a small lobed ganglion (*a*), anterior to the usual cephalic ring (*e*), which is situated below the bulb of the œsophagus. The cephalic ring (*e*) surrounds the œsophagus, and at its sides are seen two large tri-lobate ganglia (*f*), which send numerous branches to the surrounding muscular parts, and two long branches (*h*, *h*) extend backwards from them, along the sides of the abdomen, to two symmetrical ganglia

(i, i) placed above the muscular foot. Behind these are two sympathetic ganglia (k), which send filaments to the digestive organs.

1195. In the simple form of the nervous system presented by the *Carinaria Mediterranea* (Fig. 380), there is a close analogy with the ordinary disposition of the symmetrical detached nervous columns along the ventral surface of the abdomen in the inhabitants of bivalve shells. Lobed ganglia (g, h) are found in this animal at the sides of the œsophagus, and a transverse nervous band (i) connecting them, and encompassing that passage. From this nervous œsophageal ring (i) the two optic nerves pass laterally to the eyes (f, f),

Fig. 379.

Nervous system of Bulla lignaria.

Fig. 380.

Nervous system of Carinaria Mediterranea.

and the tentacular branches pass upwards and forwards to the long slender tentacula (e, e). Numerous branches extend downwards and laterally, to ramify on the muscular parietes of the abdomen, and two principal trunks (k, k), extending backwards along the ventral surface of the abdomen, meet with a large compound quadrilobate (four-lobed) ganglion (q) behind the stomach, and above the diverging muscles of the compressed foot. These two ventral (belly) detached and converging columns (k, k), extending from the œsophageal collar to the middle or pedal ganglion (q), can be traced backwards from these ganglia, along the lower surface of the ab-

dominal cavity beneath the intestine, to near the caudal extremity of the trunk. A branch, constituting the sympathetic, extends directly backwards from the brain, or œsophageal collar, and is distributed to the viscera. Numerous branches come off from the pedal ganglia (q), to ramify on the muscles of the foot and surrounding parts. The lateral ganglia of the nervous œsophageal collar are the parts from which the two principal nervous chords are derived, which extend backwards beneath the abdominal viscera.

1196. The *Buccinum* (Whelk) and the *Harpa* have the greatest

FIG. 381.

Nervous system of Harpa elongata.

portion of the ganglionic matter of the œsophageal nervous ring accumulated in a cerebral position above the entrance of the alimentary canal, as shown in the annexed figure of the *Harpa elongata* (Fig. 381).

1197. The mantle (o) is opened to show the branchiæ (d, e) and

the siphon (*c*) on the left side of the figure. On opening the anterior part of the trunk the retracted proboscis (*g*), with its muscles (*h*), are seen extending backwards to the right of the brain (*i*), which rests on the inferior turn of the œsophagus. From this cerebral mass (*i*) large nerves are seen extending forwards to the head (*b*), the tentacula, with the eyes, at their base (*s*, *s*), and to the broad fin-like anterior fold (*a*) of the long tapering foot. Other nervous chords are seen extending downwards to the ventral surface of the abdomen, and backwards to the sympathetics which supply the abdominal viscera.

1198. This gradual concentration of the ganglionic matter of the great œsophageal nervous ring of the Gasteropods into a cephalic position, may be regarded as preliminary to its enclosure in a distinct cranial covering—a condition which it attains in the *Cephalopods* (*kephale*, head; *pous*, foot).

LESSON LXXXI.

NERVOUS SYSTEM IN THE PTEROPODA AND CEPHALOPODA.

1199. These animals are named from the Greek, *pteron*, a wing, and *pous*, a foot, and are so called from the peculiar wing-like form of their sole locomotive organs, which are placed near the head.

1200. All the animals of this class are minute, the largest (*Clio borealis*) not exceeding an inch in length. They are *marine*, and found for the most part in the Arctic seas, where they exist in immense shoals. Some of them are encased in an extremely delicate shell (*Hyalea*); others, like the Clio, are naked. They constitute, especially *C. borealis*, the chief food of the Whale, which is unable to swallow any thing of larger size than the creatures now under consideration; and of these, from the smallness of its œsophagus, it can only take *one at a time.*

1201. The nervous system in the Pteropods presents the same general plan, and the same varieties of form in its cephalic masses, as we have seen existing in the Gasteropods, especially in the naked species.

1202. Thus, in the *Clio borealis*, there is a double nervous collar around the œsophagus; two small ganglia approximate to each other, to form a bilobate brain (*a*) (Fig. 382), and are placed above the œsophagus, immediately behind the lips, and indicate by their diminished size the imperfect development of the organs of the senses in this animal, which scarcely presents a trace either of eyes or ten-

tacula. Behind these central ganglia are two larger lateral ganglia connected together by a transverse band below the œsophagus, and which supply the principal nerves to the muscular-closed mantle enveloping the trunk. Two nervous bands proceed from each of this middle pair of ganglia, one of which connects them with the cerebral, and another proceeding backwards connects them with a posterior pair of ganglia, which are united by a transverse chord above the œsophagus.

Fig. 382.

Nervous system, Clio borealis.

CEPHALOPODA.

1203. The nearest approach to the vertebrated form of the nervous system is that presented by the *Cephalopods*, the highest of the mollusca, and of all invertebrata. The brain is enclosed in a distinct cranial cavity, numerous symmetrical ganglia are developed on the great nervous axis, both before and behind that organ, and sympathetic ganglia are observed in the abdominal cavity.

1204. The principal masses of the nervous system of the *Pearly Nautilus* (Fig. 383) are concentrated in the head. The supra-œsophageal part, or brain (*a*), presents the form of a short, thick, transverse, round chord, or commissure, connected at each extremity with three ganglionic masses. The middle and superior of these (*b*) supplies the eye and the inferior hollow tentaculiform organ; the anterior and inferior ganglia (*c*, *c*) meet their fellow below the œsophagus; the posterior ganglion (*d*), in like manner, joins that of the opposite side and forms a second and posterior œsophageal ring. The nerves given off immediately from the supra-œsophageal ganglion supply the muscular and other parts of the mouth, and have small pharyngeal ganglions developed upon them. The anterior œsophageal ring gives off

Fig. 383.

Nervous system of the Pearly Nautilus.

principally the nerves to the tentacula (*f, f*), and the two median ones (*g, g*) are connected with a ganglion (*h, h*), which supplies the tentacula of the inferior labial processes, and the lamellated organs on that part of the oral sheath. The tentacula nerves are continued, like those of the arms in the higher cephalopods, along the middle of the tentacle, attached by loose cellular tissue to the vessels of the part. The posterior collar gives off numerous nerves (*m*) of a flattened form, which supply the muscles of the shell. The respiratory nerves form a small ganglion (*q*) at the base of each pair of gills, from which branches are sent to those organs, and to the heart. A plexus of more delicate visceral nerves (*r*) is continued backwards along the interspace of the branchial nerves, and the chief branches are connected with a small ganglion situated upon the stomach; the ophthalmic tentacula derive their nerves (*n, n*) from the immediate vicinity of the origin of the optic ganglion. The hollow plicated process beneath the eye, regarded by some authors as the olfactory organ, likewise receives its nerves from the extremity of the supra-œsophageal chord.

LESSON LXXXII.

NERVOUS SYSTEM IN THE FISHES.

1205. The great axis of the nervous system occupies entirely a dorsal (*dorsum*, back) position in the vertebrated classes; it is enclosed in an osseous (bony) sheath or spine, which is continued over its posterior prolongation, and it is nowhere perforated by the alimentary canal.

The fibrous structure of the encephalic portion (brain) which is perceptible in the *Cephalopods*, becomes more distinct and obvious as we ascend through the vertebrated classes; and that anterior part of the nervous axis becomes likewise proportionally larger, leaving only slight traces, in the fourth ventricle, of its original opening for the passage of the alimentary canal.

The spinal chord, the medulla oblongata, the optic lobes, the cerebral, and cerebellic hemispheres, form the most constant elements of this axis, but their relative and actual developments vary in the different classes. Though much varied in the extent of its development in the different classes, there is great similarity in the successive stages of the development of this system in the embryos

of all the vertebrated animals, and great uniformity of plan in all its adult forms. Beginning with the two columns of the axis, like the two chords of a worm, it becomes reinforced by filaments from every part of the periphery, and gradually receives its ganglionic enlargements, as in all the inferior tribes, where they are most required by the developing organs of the body. The great sympathetic or nervous system of *organic life*, which is extended along the upper, or dorsal side of the symmetrical axis in the inverted bodies of the articulata, is here developed along the ventral or under surface of the spino-cerebral (*spine*, *brain*) axis, and like the sympathetic system of the highest articulata, it is enclosed with the viscera, in a cavity distinct from that which envelops the nervous axis of animal life.

1206. In the long, worm-like form of the lowest fishes, as the *Lamprey*, the *Pride*, and the *Gastrobranchus*, the two slender columns extending along the back, and scarcely protected by a cartilaginous (*cartilage*, gristle) sheath, are nearly without cerebellum, and destitute of ganglionic enlargements in their course to the head, where the minute cerebral elements are enclosed, like the ganglia of a Cephalopod, in a cartilaginous tube, consisting of a single piece.

1207. This simple condition of the axis, presented by the lowest fishes, resembles the primitive development of this system in the highest vertebrata before the extremities began to shoot from the sides of the trunk.

1208. In fishes, as in Cephalopods, where a large exterior surface of the skull is required for muscular attachments, the minute brain does not fill the cavity of the cranium, and the space between the *dura mater*, which lines the skull, and the *pia mater*, which invests the cerebral organs, is occupied by the soft, transparent, semi-fluid cellular tissue of the arachnoid coat, which passes down likewise through the vertebral canal, enveloping the spinal chord.

1209. The spinal chord is nearly equal in its development throughout the vertebral column, even in many of the osseous fishes, from the smallness of the arms and legs not requiring those enlargements which we observe in most higher animals, where the nerves are larger and more powerful extremities are given off.

1210. In species which have the arms of great magnitude, as *Rays*, and *Flying-fishes*, there is a proportionate development of the upper enlargements of the spinal chord.

LESSON LXXXIII.

NERVOUS SYSTEM IN FISHES, CONCLUDED.

1211. In the *Trigla lyra* (Fig. 384), where the pectoral fins are of great size, a series of ganglionic enlargements (*b*, *b*) of the spinal chord (*a*) are observed at its upper part, which corresponds in number with the number of the large detached rays of the pectoral fins presented by the different species, *Trigla cucullus* having five enlargements and five detached rays, and the *Trigla lyra* having six of each.

1212. The demonstration of the figure is as follows: The spinal chord is seen at *a*. The medulla oblongata which consists of six ganglionic enlargements at *b*, *b*. At *c*, *d*, the cerebellum is seen, and the cerebrum at *f*. In this superior portion of the brain, the optic lobes (*e*, *e*), the olfactory lobes (*g*), and the olfactory nerves (*h*) are found.

FIG. 384.

Nervous system, Trigla lyra.

FIG. 385.

Brain, Conger eel.

1213. The posterior extremity of the spinal chord is sometimes sensibly enlarged where nerves proceed to the muscles of a large caudal (tail) fin, and in abdominal fishes (an order so called from the attachment of the ventral fins to the abdomen, behind the pectorals, or *chest* fins), an enlargement is observed, corresponding with the ventral, or *belly* fins.

1214. In front of the medulla oblongata and cerebellum in osseous fishes, there are three pairs of rounded lobes placed in front of each other along the floor of the cranium, and occupying but a small portion of that capacious cavity, as seen in the brain of the *Conger eel* (*Murœna conger*, Fig. 385), where these three pairs of lobes are nearly equally developed and similar in form.

1215. The spinal chord is shown at *a*; to this succeeds the cerebellum (*b*). The cerebrum is marked *e*, containing the optic lobes (*c*), the olfactory lobes (*f*), the olfactory nerves (*g*, *g*), and the pineal gland (*d*).

1216. The posterior pair of lobes (*c*), immediately before the

cerebellum (*b*), are the *optic lobes*, which are hollow internally, as in the human embryo, and give origin to the principal fibres of the optic nerves.

1217. The second or middle pair of lobes (*e*) are the *cerebral hemispheres*, which here, as in the human embryo, are destitute of internal ventricles, and without external convolutions.

1218. The anterior pair (*f*) are the olfactory tubercles, which are entirely appropriated to the olfactory nerves (*g*, *g*).

1219. In the *Trigla lyra*, where the medulla oblongata (Fig. 384, *b*, *b*) is marked by ganglionic enlargements, and the cerebellum (*c*, *d*) is proportionally small, the optic lobes (*e*, *e*) are much larger than the cerebral hemispheres (*f*), and the olfactory tubercles (*g*) are much inferior in size.

1220. In most fishes, as in the earliest condition of the human brain, the *optic lobes* are larger than the hemispheres; they are smooth and gray on the outer surface, and destitute of the transverse sulcus (a *furrow*), which gives them a *four-lobed* (quadrigeminous) appearance in the adult mammalia; they are hollow within, and have their inner walls lined with white medullary fibres. The ventricles of the optic lobes communicate freely with each other, and they open behind by a narrow aqueduct, into the fourth ventricle beneath the cerebellum.

1221. The interior white medullary walls of these two lateral cavities meet above on the median line, and form an extended commissure; they descend along the median line to form a prominent ridge, but not a complete septum, between the ventricles.

1222. Finally, the *optic lobes* of fishes, like their medulla oblongata, are larger in proportion to the cerebral hemispheres than in any of the higher vertebrata, and they present the same great proportions the earlier we observe them in the human embryo.

LESSON LXXXIV.

NERVOUS SYSTEM IN REPTILES.

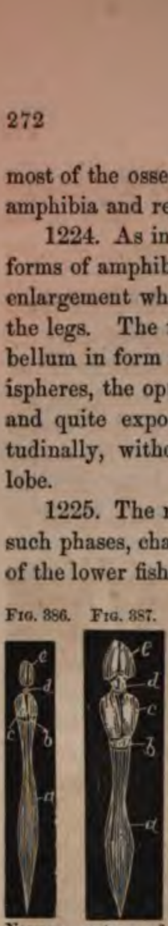
1223. In the *Amphibia*, and in the larva state of those which lose the gills, the spinal chord, the medulla oblongata, and the cerebral parts contained within the cranium, present the same proportions and general conditions which we observe as permanent characters in

most of the osseous fishes; but the cerebellum is generally smaller in amphibia and reptiles than in all the other vertebrata.

1224. As in the lower fishes, the spinal chord in these inferior forms of amphibia is prolonged, small, and tapering, without distinct enlargement where the nerves usually come off to the arms and to the legs. The medulla oblongata is yet broad and lobed, the cerebellum in form of a very small median transverse lobe without hemispheres, the optic lobes large, gray, smooth without, hollow within, and quite exposed, and the cerebral hemispheres extending longitudinally, without internal ventricles, and smaller than the optic lobe.

1225. The metamorphosis of the animals of this class, prone to such phases, changes the condition of their nervous system, from that of the lower fishes, to nearly that of the reptiles above them, in which no metamorphosis occurs; and these changes in the nervous system are effected so rapidly, that we can perceive a marked advancement in the development of the nervous system of the *Tadpole* produced in one day.

FIG. 386. FIG. 387.



Nervous systems of Frog on fourth and fifth days.

1226. In the Tadpole of the common frog, on the fourth day (Fig. 386), the spinal chord is perceptibly enlarged at its posterior part (*a*), and also the medulla oblongata. The cerebellum (*b*) is scarcely visible, extended across the median plain; the optic lobes (*c*), and the cerebral hemispheres (*e*) are small, narrow, and so far separate longitudinally as to expose the optic thalami (*d*).

On the following, or fifth day (Fig. 387), besides the general increase of the spinal chord (*a*), the cerebellum (*b*) is perceptibly enlarged, the optic lobes (*c*) are proportionately broader and shorter, and the cerebral hemispheres (*e*), increased in every direction, begin to extend backwards over the optic thalami (*d*). As the tadpole advances in its development, and the legs and arms are extended from the sides, the posterior and middle enlargements of the spinal chord are proportionally increased, the cerebral hemispheres enlarge, but they present no convolutions or ventricles. The anterior extremity of the chord is enlarged from the first, as it gives origin to the cranial (head) nerves, and the posterior end is enlarged for the *cauda equina* (the termination of the spinal chord in man, and other animals, is supposed to represent a Horse's tail, and is thus named—*cauda*, a tail; *equina*, a Horse).

1227. The changes effected in the nervous system of the higher amphibia closely resemble those produced by development in the human embryo. Their sympathetic nerves, and ganglia, too, are more distinct than in the class of fishes.

1228. By comparing the nervous system of the *adult* Frog (Fig. 388), with those of the tadpole during the period of early development, great and important changes will be apparent. Thus, the olfactory ganglia and nerves (nerves to the nose), which did not at all appear before, are now well formed (*a*); the cerebal hemispheres (*b*) are greatly enlarged, the optic lobes (*c*) well developed, and the cerebellum (*d*) remains so small that it does not cover the *fourth ventricle*, or cavity left by the divergence of the columns of the spinal chord (*e*); the cauda equina (*f*,*f*) is also well produced at the period of mature growth.

FIG. 388.

Nervous system of adult Frog.

FIG. 389.

Brain of the Turtle.

1229. From the foregoing it will be seen that the chief advance in the development of the Reptile brain, as compared with that of Fishes, consists in the greatly increased size of the cerebral hemispheres over the optic lobes, but the cerebellum is smaller—so small in the Frog that it does not even cover the fourth ventricle, and this is common to nearly the whole class.

In confirmation of these facts a figure is given of the brain of the Turtle (Fig. 389); the olfactory ganglia (*a*) are largely developed, and form, with the eyes, the most important organs of special sense. The cerebrum (*b*) is enormously produced, as compared either with the optic ganglia (*c*), or the cerebellum (*d*).

LESSON LXXXV.

NERVOUS SYSTEM IN BIRDS.

1230. In this class the cerebral hemispheres attain a great increase of development, and arch backwards, so as partly to cover the

optic ganglia, and these are separated from each other and thrown to either side.

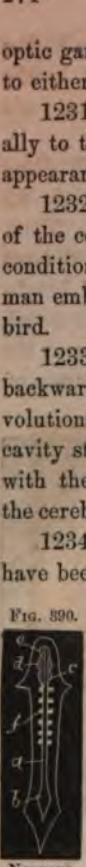
1231. The cerebellum also is much increased in size, proportionally to the medulla oblongata and its ganglia; there is, however, no appearance of a division into hemispheres.

1232. The optic ganglia bear a considerable proportion to the size of the cerebrum; they are still hollow, as they are in the embryo condition of man. We shall hereafter see that the brain of the Human embryo bears comparison in many respects to the brain of the bird.

1233. The great increase of the cerebral hemispheres, arching backwards over the Thalami, and optic ganglia, but destitute of convolutions, and imperfectly connected by commissures,—the large cavity still existing in the optic ganglia, and freely communicating with the third ventricle—together with the imperfect evolution of the cerebellum—make the correspondence in the two very remarkable.

1234. In the earlier periods of the Old World, Birds appear to have been connected with the Reptiles, through the flying Lizard, or *Pterodactylus*, remains of which animal are now only found in a fossilized condition.

Fig. 390.



Nervous system of Chick.

1235. It is very instructive to examine the brain of the chick, after two days of incubation (Fig. 390). We here see that the two halves of the spinal chord (*a*) are united posteriorly, and form the vesicular enlargement (*b*), corresponding to the cauda equina and pelvic dilatation of the adult. The cervical and dorsal vertebræ begin to embrace the anterior (*f*) portion of the chord, and three vesicular enlargements are seen on the cephalic portion of the nervous axis. The posterior (*c*) of these enlargements forms the rudimentary lobes of the medulla oblongata, the middle dilatation (*d*) constitutes the outline of the optic lobes, the anterior (*e*) and smaller cephalic enlargement forms the embryo condition of the cerebral hemispheres in the chick, and all these lobes are disposed in a longitudinal direction, as they are found in fishes, and in the embryos of mammalia.

1236. In the brain of the adult *Stork* (Fig. 391), the large cerebrum (*d*, *e*) is partially divided into lobes; it covers the optic thalami (*thalamus*, a bed-chamber, bed of the optic nerves), and contains a small ventricle, which extends forwards to the olfactory (nerves of smell) tubercles (*f*).

1237. These latter commence from two medullary tracts (*h*) on

the inferior surface of the hemispheres, and taper forwards to the olfactory nerves. The optic lobes, from whence the optic nerves arise, are shown at *c*, the nerves of motion of the eye, or *motor oculi* (*g*), are also well developed.

1238. The large cerebellum (*m*), with its lateral lobes (*l*), is also well seen; the medulla oblongata (*b*) terminates in the spinal chord (*a*).

1239. An illustration is offered of the brain of the Buzzard

FIG. 391.

Brain of the Stork.

FIG. 392.

Brain of the Buzzard.

(Fig. 392); the olfactory ganglia are entirely concealed, in this view, by the great size of the cerebral hemispheres (*a*). The optic ganglia (*b*) are seen of large size; the cerebellum (*c*), and the pineal gland (*d*)), with (*e*) the spinal chord, completes the view.

1240. The sensitive spinal nerves of birds have the ganglia larger, and approximate more nearly to their origin than in reptiles; and from the retraction and high termination of the spinal chord, as well as the comparative magnitude of the legs in this class, the posterior ganglionic enlargement is remarkable for its size, and at this place the motor and sensitive roots pass out through separate foramina (holes) of the numerous sacral (*sacrum*, the back) vertebræ.

The twelve pairs of cranial nerves are distinct, as in reptiles and mammalia. The smallness of the facial nerve corresponds with the immobility and insensibility of the superficial parts of the face, and the magnitude of the acoustic nerve, with the great development of

their internal ear, and their acute sense of hearing, especially in nocturnal birds.

The spinal nerves are chiefly cervical (*cervix*, the neck), and sacral (*sacrum*, the lower part of the back), from the number of vertebræ composing these parts of the column.

LESSON LXXXVI.

NERVOUS SYSTEM IN MAMMALIA AND MAN.

1241. It has been shown that the nervous system in the lowest animals possessing such a structure, exists in the form of a *single* chord, presenting a lengthened axis, and in the *Entozoa* only one ganglion is found.

1242. To this succeeds a *double* chord, and with this single or double chord, *ganglia*, or knots of nervous matter, varying alike in situation and number, are associated.

1243. Thus, in the lower *Articulata*, we find a ganglion, or little brain, or nervous mass of reinforcement, placed in the centre of each segment of the body, which are motor in their function, and supply nerves only to the system of muscles found in the segments respectively. The nerves of distribution are uniform in number, and distributed to similar structures in each instance—the only exception being in relation to the supra-æsophageal ganglion, or brain, the nerves proceeding from which, with the exception of the sympathetic nerves, are distributed solely to the organs of special sense.

1244. In the *Leech* we found only eyes to be supplied, and thus the brain distributed only *optic nerves*, and may be considered as simply an *optic ganglion*. In this animal the lower portion of the brain, infra-œsophageal ganglion, greatly exceeds the superior portion in size—the muscles to be supplied with nerves being much more abundant than the organs of special sense.

1245. In proportion as organs of sense are increased, so will the brain be found to increase in size, and the greater will be the number of nerves distributed from its superior portion; compared with the Leech, a Caterpillar claims a much higher organization, and hence the superior development of its brain, and the vast assemblage of nerves in connection with it. In the *Cirripeds*, no organs of special sense were found, neither is a superior portion of the brain developed, but the ganglions connected with the double chord, are mo-

tor in their function, with the exception of the sympathetic nerves originating from the supra-œsophageal loop. In the *Myriapods*, however, a large and well developed brain is found, to supply the increased number of the organs of special sense, and to originate a well formed sympathetic system. In *Insects* another and remarkable change, of a strictly progressive character, awaits us. In their larval, or infantile condition, their energies are in abeyance, and their organs of special sense are few, compared to their condition in the perfect insect; the superior portion of the brain, therefore, is much smaller than it is hereafter destined to become. The energy, activity, and great irritability of the perfect Insect, contrasts remarkably with the dull, sluggish, almost impassible life of the same animal in its young condition. In a caterpillar, any one segment or ring of the body (except the head) is like all the rest, and has the same functions, even of locomotion, to perform—hence the necessity of a ganglionic enlargement, or little brain in each segment, to keep up, or maintain, the nervous force necessary for the due performance of their functions respectively. The brain is much larger than their inferior portions in the perfect Cockroach (Fig. 417), and Mantis religiosa (Fig. 419).

1246. In the *bivalve-mollusca*, we find a creature in which the nutritive system appears to be developed at the expense of all the other organs; consequently there is little special sense, and no need of nerves to supply organs that do not exist.

1247. Destitute of vision, optic nerves are unnecessary; devoid of smell and taste, there are neither gustatory nor olfactory nerves, and the brain (or that which is analogous to it, as some authors suppose) is reduced to the two cephalic ganglions, which are placed on either side of the œsophagus, and much smaller in size than the branchial ganglia. From all analogy of the distribution of nerves from special centres, and the organs they supply, the cephalic ganglia of the bivalve mollusca appear to constitute, not the *superior*, but only the inferior surface of the brain. Headless, and entirely destitute of organs of special sense, there is no need of a supra-œsophageal ganglion, and none such is developed; the branchial ganglions, with their mixed function, appear to be the most important. The same remarks apply to the still lower *Tunicatæ* and *Terebratulæ*.

1248. But in the *Slugs* and *Snails*, whether naked or testaceous (*testa*, a shell), we find animals endowed with that superior organization that renders a higher development, no less than a local position and concentration of the brain, imperatively necessary. With a

head, and abundant organs of special sense, a well developed supra-œsophageal ganglion is found.

1249. From these animals we make a rapid ascent to the *fishes;* in the lowest of these, the anterior portion of the double chord displays a succession of five pairs of ganglia.

1250. The higher fishes, and the amphibious reptiles, appear to have a different disposition of these primitive ganglia. The first two have become fused into a single ganglion, and then follow only three pairs of symmetrical ganglia. But if the larger pair be unfolded after being hardened in alcohol, it will then be seen that the whole number of ganglia exists, but that four have become concealed by a thin covering that has spread across them.

1251. This condition of the brain carries us upwards in the scale of being, even to the *mammalia;* in the dog, or cat, for example, we find, first a single ganglion, the cerebellum; then three pairs following each other in succession; and if we unfold the middle pair, we shall be at once convinced that it is indeed composed of two pairs of primitive ganglia, concealed by an additional development.

1252. Again it will be observed that the primitive ganglia of opposite sides, at first separate and disjoined, become connected by means of transverse fibres of communication, or commissures. The office of these commissures is the association in function of the two symmetrical portions.

1253. Carpenter, in his human physiology, has truly said, "Hence we arrive at the general and important conclusion, that the brain among the lower animals consists of *primitive chords, primitive ganglia* upon those chords, and *commissures* which connect the substances of the adjoining ganglia, and associate their actions."

1254. In the development of the cerebro-spinal axis of man, the earliest indication of the spinal chord is presented under the form of a pair of minute longitudinal filaments placed side by side.

1255. Upon these, towards the anterior extremity, five pairs of minute swellings are observed, not disposed in a straight line, as in fishes, but curved upon each other so as to correspond with the direction of the future cranium.

1256. The posterior pair soon becomes cemented upon the middle line, forming a single ganglion; the second pair also unite with each other; the third and fourth pairs, at first distinct, are speedily veiled by a lateral development, which arches backwards and conceals them; the anterior pairs, at first very small, decrease in size and become almost lost in the increased development of the preceding pairs.

1257. This is represented to some extent, in three views of the human brain from an Embryo (Figs. 393, 394, and 395). The first (Fig. 393) is seen from behind; *a*, the optic lobes, or, as they are called, from their four-lobed character in the human subject, *corpora quadrigemini;* *b*, the cerebral hemispheres; *d*, cerebellum; *e*, medulla oblongata.

1258. The second (Fig. 394) and the third (Fig. 395) have the same letters of reference down to *e;* the second is a side, and the third a sectional (perpendicular) view; *g*, the floor of the third ventricle; *i*, olfactory nerve; *f*, optic thalamus.

1259. We see here a chain of resemblances corresponding with the progressive development observed in the lower animals; the

Fig. 393.

Brain of human Embryo, from behind.

Fig. 394.

Side view.

Fig. 395.

Sectional view.

human brain passes through the phases of improving development, which distinguishes the highest from the lower creatures; and we are naturally led to the same conclusion with regard to the architecture of the human brain, that we are led to establish as the principle of development in the inferior creatures—that it is composed of *primitive chords, primitive ganglia* upon those chords, *commissures* to connect the ganglia, and *developments* from those ganglia.

The human brain, therefore, may be supposed to consist of a number of elements, which are more or less diffused amongst the lower animals, and which in them constitute the several ganglionic masses that we find them to possess.

The more widely these elements are diffused, and the more frequent the repetition of these little brains, the lower the individual in the scale of being.

Thus, the *Nereis nuntia*, with its 1,000 ganglions, is lower than a Caterpillar; which is, in its turn, lower than the perfect Insect; for in the latter we find a greater concentration of the Cerebrum, to supply an increased number of organs of special sense, all of which have attained a higher, a more refined development.

The organs of locomotion in the perfect insect have also become

concentrated; hence the absorption of ganglions in the abdomen, where they are no longer wanted, and the deposition of increased nervous matter in the thoracic ganglions, where it is imperatively needed.

These facts are beautifully illustrated in the disparity of size and number of the nervous centres (ganglions) of the active Slugs and Snails, as compared with the passive bivalve-mollusca.

It has been remarked, with great propriety, that, in the progress of his development, man passes successively through all those phases of existence at which the remainder of the animal kingdom, respectively, remain permanent.

He has never been, in reality, an Animalcule, an Insect, a Mollusc, Fish, or Reptile, but he has passed through the conditions at which they remain stationary.

It has been shown that, in the development of the human brain and spinal chord, two nervous chords, unprovided with ganglia, first exist.

The next stage exhibits a single ganglion, and at this moment the human embryo is on the same plane with those animals in whom a sole ganglion becomes permanent; as the ganglia increase slowly in number, so the embryo attains a higher rank in the scale of being.

But it is equally true that, prior to the production of even a nervous chord, a still lower type was indicated, for, although the statement is somewhat humiliating to the "lord of creation," we yet commence our career in a form far less *animal* than *vegetable*. At one period of the development of the ovum, a single cell exists; presently it divides into two; these sub-divide into four, and this process continues until the yelk consists entirely of a congeries of cells.

Now this is precisely the plan upon which, as we have seen, plants owe their being, and in both kingdoms the primary cells are employed to organize the tubular tissues—spiral and lactiferous vessels in plants, nutrimental organs and blood-vessels in animals.

The probability is that man possesses a stomach, not only before the advent of any portion of the nervous system, but prior to the formation of an intestinal canal, thereby reducing him to the level of the polypes. When the intestine is superadded, he has attained a higher grade of development.

Again, the stomach is completed, like that of the polype, with only one aperture; when other cells are added, to form a rudimentary and short intestine, the septum (partition) becomes absorbed.

So, too, blood-vessels are formed, and the blood freely circulated long before the existence of a heart. This may be beautifully seen in the ova of Fishes, and especially in the egg of the domestic fowl, on the fourth day of incubation.

But the character of this circulation is more nearly allied to the vegetable than to the animal kingdom, and closely resembles the circulation, or rotation, as it is called, so beautifully seen in the hairs of many plants, Tradescantia, the cells of Chara, Nitella, Valisneria, Frog bit, &c.

Still, in his early development, man maintains his supremacy, for, during these progressive changes which take place in secret—unseen—his external form is always human!

LESSON LXXXVII.

NERVOUS SYSTEM IN MAMMALIA AND MAN, CONTINUED.

1260. The spinal chord of the *adult* man (Fig. 396, *b*, *i*) is smaller, compared with the cerebral mass contained within the cranium, than in other mammalia, and short, from the want of caudal prolongation of the trunk; its posterior and middle enlargements (*c*, *d*) are conspicuous, and of a lengthened form, from the magnitude and number of the nerves which proceed from them to the sacral extremity; the cauda equina (*a*, *b*) is of great length; the motor roots (nerves of motion, *l*, *l*) and anterior columns are smaller than the sensitive, and the ganglia of the posterior or sensitive roots (*k*) of the spinal nerves are here larger than in other mammalia.

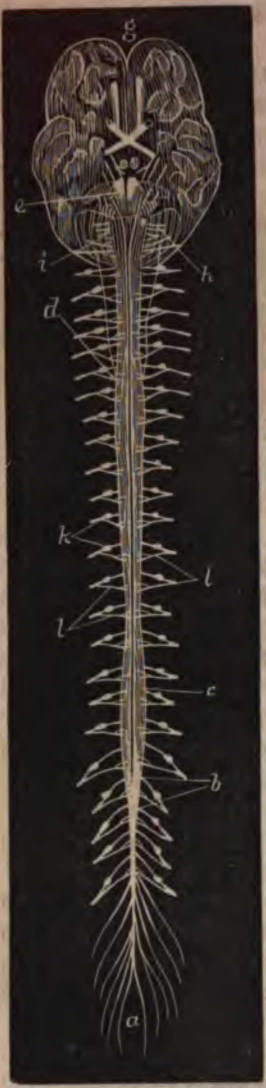
1261. The medulla oblongata, though comparatively small, has its component fasciculi most deeply marked, and the quantity of internal ganglionic matter in the course forwards of these white fibrous fasciculi corresponds with their great development in the human cerebral and cerebellic hemispheres, where the convolutions (*g*) and laminæ (*h*, *i*) surpass in number and depth those of almost all inferior animals.

1262. It now only remains to ascertain the microscopical characters which distinguish a nerve and a ganglion in all animals; and these characters are found to be remarkably constant.

1263. The fine, white chord, called a nerve, when placed under the microscope, is found to consist of three tissues; of these, the

outer one is a delicate, structureless sheath, called the Neurolemma (*neuron*, a nerve; *lemma*, a sheath).

FIG. 396.



Cerebro-spinal axis (brain, spinal chord) of man.

1264. Within this sheath are the nerve fibres, as they have been called, which are really tubes containing a medulla, or pulp.

1265. These ultimate tubes possess a structureless sheath of extreme delicacy; they are found composing the nerves of all descriptions; belong as much to the gray, or cortical, as to the white, or medullary substance of the brain, of the spinal chord (where it exists), and of the ganglia.

1266. The pulp, contained in the tubes, known as the "white substance" of Schawn, who first described it, is, when quite fresh, perfectly homogeneous, fluid, and viscid, like a thick oil, but every method known of preserving it, coagulates or otherwise alters it. For this purpose a saline solution (eight ounces of salt, to one quart of water) appears to be the best adapted, as it changes it the least.

1267. It has been remarked that it readily dissolves in water (Mollusca), leaving only a series of empty tubes, and this is true even in the human subject. Preparations of nerves, made for the microscope, are subject to pressure, and under its influence the whole contents of the nerve tubes (in time) become squeezed out.

1268. In addition to the white substance of Schawn, these tubes contain in their centre a tube of the most delicate transparency; this is called the axis-cylinder.

1269. A figure of the axis-cylinder obtained by pressure from a preparation of the median nerve (human), is given in Fig. 397. The same preparation also displays the white

substance (Fig. 398), obtained by the same agency; nothing can exceed the transparency, combined with brilliancy, of these two last preparations. It will be seen that the white substance consists of nucleated cells.

1270. Another axis-cylinder, containing some corpuscles of the white substance, copied from the same preparation, is given (Fig.

FIG. 397.

Axis-cylinder.

FIG. 398.

White substance of Schawn; from the median nerve, human.

FIG. 399.

Axis-cylinder containing white substance, median nerve.

399); it will readily be perceived that they differ considerably in size. A common occurrence is, to find the axis-cylinder with the white substance covering the termination of it (Fig. 400).

1271. The appearance of the tubes of the median nerve is shown in Fig. 401, the granular contents indicating the white substance.

1272. The nerve tubes of the sympathetic system differ from

FIG. 400.

White substance covering termination of axis cylinder.

FIG. 401.

Median nerve.

FIG. 402.

Sympathetic nerve, human.

those just described; firstly, they are so much smaller that they do not exceed one-third the diameter of the former; and, secondly, they do not present the two distinct substances within the tubular investment, which has been shown to exist in the ordinary nervous tubuli.

1273. A figure of the tubes of a sympathetic nerve is given at Fig. 402; the contents of these tubes appear to be perfectly homo-

geneous, although, when treated with acetic acid, they exhibit cell nuclei (a).

1274. In addition to nerve tubes, which, as before remarked, are common to all nerves, ganglions possess solid corpuscles, liable to much variety of shape; these have been (erroneously) called "ganglion globules," but when removed from the tissue many of them present an irregular figure, and are caudate (tailed). A figure of a thin section of a ganglion of the neck (human) is given (Fig. 403); these corpuscles are extremely numerous, and, when seen in their natural situation, have a reddish appearance.

FIG. 405.

Nerve of B. Americana.

FIG. 404.

Corpuscles from the gray substance of the spinal chord, human.

FIG. 403.

Sympathetic ganglion of the neck, human.

Removed from the tissue with which they are connected, these corpuscles are very variable in size and shape.

1275. The ganglion corpuscles are common to the gray or cortical substance on the external surface of the Brain, and of all the ganglia, and the corresponding gray matter in the interior of the human spinal chord. A view of these corpuscles, obtained from the latter situation, is given in Fig. 404; in addition to their caudate terminations, these corpuscles also present nuclei.

1276. The remarkable constancy in the structure of nerve and ganglion in the animal kingdom has been adverted to, and illustrations obtained from a class as low as the Insects will be sufficient to prove the statement. A portion of a nerve given off from the last (caudal) ganglion of a Cockroach (*B. Americana*) is given in Fig. 405; the Neurolemma (nerve sheath) is distinctly seen on either side (a, a), and within it the nerve tubes containing the white substance.

FIG. 406.

Ganglion, B. Americana.

1277. A section of the caudal ganglion of the same insect (Fig. 406) displays the nerve tubes greatly reduced in size, and the crowded ganglion corpuscles

(*a*), which, in the preparation, are slightly red, as they are in man. All the figures of nerve tissue have been drawn under a one-fourth object glass, and to scale.

LESSON LXXXVIII.

NERVOUS SYSTEM IN MAMMALIA AND MAN, CONCLUDED.

1278. *Vascularity of Nerves.*—Nerves, like muscles, appear to be highly vascular; the vessels, however, will be found restricted to the outer sheath, and are not allowed to penetrate amongst the tubular structure. This rule also applies to the brain, which is nourished and sustained, not by vessels passing into the interior of its substance, but by a highly vascular membrane, the *pia mater*, which everywhere surrounds it.

1279. Nerves, it is well known, always accompany the arteries and veins into whatever tissue they are distributed, but the nerves do not gain any advantage from their near proximity to arteries during the course of their joint distribution, for the nerves carry their own vascular system with them.

Fig. 407.

Nerve injected.

1280. In good injected preparations the nerves will be found to have participated in the general success; if one of these be dissected out, placed on a slip of glass, dried, and mounted in Canada Balsam, the probability is that an appearance will present itself, under the microscope, similar to Fig. 407, which shows an injected nerve. On one side of the sheath will be seen an artery (*a*), and on the opposite side a vein (*b*), and these two vessels are connected by a series of capillaries (*c*), which ramify everywhere on the surface of the sheath.

1281. Such a preparation as the foregoing, is very instructive, as it teaches a lesson not easily forgotten; it demonstrates the peculiarity of the distribution of vessels in this particular tissue, and enables one to detect a nerve, under circumstances in which it would otherwise elude detection.

1282. In a portion of human pericardium (the bag in which the heart hangs) very minutely injected, and presenting a most gorgeous sight under the microscope, three somethings are seen entering the tissue at a particular point, somewhat deep seated, and to some extent veiled by a plexus of capillaries belonging to that layer of tissue which covers them; what are they? Many circumstances lead to the conclusion that the outer vessel on one side (*b*, Fig. 408) is an artery, distributing blood to the pericardium, and that the outer vessel, on the opposite side (*a*), is the vein, receiving and returning the blood from this tissue; but what is the third something which lies between them? Let us examine it closely, and see if we can discover what it is; two vessels make their appearance, one on either side of this something—the one is much smaller than the other, and both appear to be connected with the capillary plexus (*c*) ramifying between them; no connection whatever appears to subsist between the outer vessels

FIG. 408.

Portion of human pericardium.

FIG. 409.

Vascularity of a ganglion, with the vessels of supply and return.

of the unknown tissue and the artery and vein outside of it; the question hence arises, *in what* tissue is such a distribution a peculiarity? To this there can be but one reply—*a nerve*—and this something which, in the dried state of the tissue, more nearly resembles another blood-vessel, is indeed the nerve which invariably accompanies the artery throughout its distribution.

1283. If the circulation of the blood to a nerve be peculiar, it is no less so to the ganglions; for an example, a copy is given (Fig. 409) of a preparation of a sympathetic ganglion of the neck (human).

1284. Here the artery and vein are not at all connected with the tissue to be supplied, but the former, while passing in its course of general distribution, gives off a twig (*a*) to the ganglion, which instantly breaks up into a plexus of capillaries, which ramify all over

the entire surface of the ganglion, and ultimately yield up their contents, by another twig (*b*) to the vein, which passes it into the jugular vein, and thence to the heart.

1285. Such, then, are the peculiarities which characterize the vascular system of nerves and ganglia, and by which they may be at all times recognized, as no such distribution pertains to any other tissue.

LESSON LXXXIX.

ORGANS OF SPECIAL SENSE.—THE EYE.

1286. Want of space in this small volume will not permit a full inquiry into the subjects which form the title of this lesson, but one organ, from its almost universal distribution in the animal kingdom, together with its importance, claims special attention—the Eye.

1287. As far as our knowledge of it extends, the eye is strictly an optical instrument—a camera—and as capable of performing correctly in death, as in the living organ. To prove this fact it is only necessary to remove, carefully, the posterior portion of the sclerotic coat of the fresh eye of a Sheep or an Ox, leaving untouched the retina. If the eye, thus prepared, be presented to any object, a minute, inverted, and most beautiful view of the picture will appear upon the retina, arrayed in all its natural colors. If the picture so formed be magnified with a lens of moderate amplifying power (one inch, or 1½ inch focus), a very charming sight will be offered to the spectator.

1288. A well formed visual organ appears to require the following parts: a transparent cornea, or outer covering; an aqueous (watery) humor; an iris, or curtain of the eye, to limit and control the quantity of light to be admitted; a crystalline lens; a vitreous, or glassy humor; a pigment or paint, frequently but not always black, to absorb the excess of light which has entered the eye, and thereby give increased sharpness and intensity to the picture; a retina, or thin membraneous expansion of the optic nerve, forming the white curtain (similar to the ground-glass of a camera) upon which the images are depicted; and finally, an optic nerve, whose function it is to transmit faithfully to the brain, the full particulars of color, and general appearance of the picture formed upon the retina.

1289. That the combination of these tissues is necessary to the production of vision, is evidenced by the fact that they are all, or nearly all, found in various stages of modification, down to animals of otherwise lowly organization.

1290. There are, however, many animals altogether destitute of eyes, and yet they are visibly affected by light. This is especially well seen in the Animalcules, Zoophytes, and others, where some of them (Hydra) seek the light, and others (Actinia, and many other Zoophytes) contract their bodies, and shun its influence.

1291. Plants, guided by light, open or close their flowers and their leaves, and follow with flowers expanded the daily course of the sun, or seek his light with branches and leaves slowly moving in the direction he takes; yet they possess no nervous system, neither do the animals above mentioned, but both appear to be influenced by perceptions altogether unknown to us.

1292. Some authors (Ehrenberg and others) have supposed that many animals, acknowledged to be destitute of a nervous system, possess eyes; thus red spots seen in many (supposed) animalcules, to say nothing of other lowly organized creatures, have been described by Ehrenberg, as visual organs, notwithstanding that many of these have subsequently been discovered to be plants!

1293. This red coloring-matter, so prominently developed in the lowest plants, as in the plant called "*Red snow;*" the *Protococcus pluvialis*, found in rain-water; the *Hœmatococcus sanguinea*, found frequently on stale bread; is but a slightly altered chlorophylle, and into which it can be converted, made green.

1294. These facts clearly demonstrate the fallacy of attributing the function of vision to the red spots, unless supported by more convincing testimony than mere color. Eyes sometimes have a reddish tint from the red-brown pigment which shows through the transparent cornea.

1295. The possession of eyes in the Radiate sub-kingdom, appears to be open to much doubt, notwithstanding that visual organs have been claimed for the Medusæ, Starfishes, &c.

1296. In the Articulata, on the contrary, there is no question of their very general development, although they are not found in the *Epizoa*, generally, nor in the *Cirripeds*, at all.

LESSON XC.

THE EYE IN THE ANNELLATA, CRUSTACEA, MYRIAPODS, AND INSECTS.

1297. In the *Annellata* (red-blooded worms), eyes are constantly found, and in variable number; thus in the several species of *Planaria*, they vary from one to three pairs, and in one species (*Prostoma armatum*) the head is literally covered with them.

1298. In the medicinal Leech (Fig. 362) there are ten simple eyes; in *Nereis nuntia* there are four large eyes on the upper part of the head, and nearly one hundred smaller visual organs disposed in rows and groups on all the prominent lobes about the mouth.

1299. But in the higher forms of this class the eyes are reduced to two. In all these animals the eyes consist of a transparent cornea, a minute crystalline lens; a pigment, not always, but generally black, and an optic nerve; whether other organs are superadded is not known, the extreme minuteness of the eyes forbidding further investigation.

1300. In the higher forms of *Crustacea* (Lobsters and Crabs), the eyes are pedunculated and movable, by means of muscles inserted within their sclerotic covering; in the inferior Crustacea, they are sessile (sitting close upon the body, without support) and immovable, and in the lower Crustacea the two sessile eyes are frequently united on the median plane, and appear to form but one organ (*Monoculus*, *Daphnia*, &c.).

1301. The eyes themselves are constructed on the same plan as those of Insects, hereafter to be described, with one remarkable exception: the facets in the transparent cornea of Insects are hexagonal (see Fig. 420), but in the Lobster they are perfectly square (Fig. 410), and resemble a ruled glass micrometer; moreover, it consists of a series of laminæ (plates). It will be shown hereafter that in the Insect eye a great tendency to the square form of the facet prevails, notwithstanding it is always found associated with the pure hexagonal figure.

FIG. 410.

Transparent cornea, Lobster.

1302. In the Myriapods (Centipedes, Iulidæ) the eyes of some species resemble those of the Annellides, whilst others approximate to the Insects; most of them present numerous separate simple

eyes, grouped together on the two sides of the head. The eyes of *Scolopendra* (Centipede) consist each of a group of about twenty-three small, distinct eyes, approximated and placed in lineal rows, and the aggregated eyes of Iulus are also composed of several rows.

1303. In Insects the eyes, like most other organs of the body, attain a high degree of development; moreover, two kinds of visual organs are found in many of them, one series of eyes being adapted for long, and the other for short sight. The great Dorr-beetle, or May-bug, as the *Melolontha vulgaris* (Cockchafer) is commonly called, is a familiar example of an Insect endowed with very short vision. Persons walking in the fields, especially at twilight at the latter end of the month of May, or during June, will find these Insects constantly striking them in the face, and flying against other parts of their body, with so much force that the creature frequently falls, as if stunned by the concussion.

1304. The facetted, or compound eye, so conspicuous in all the perfect insects, appears to have but a short focal range, and even this differs to a large extent, as may be seen by the superior and remarkable convexity of these eyes, in many of them.

1305. Those insects which feed on the juices of plants, or animals, require very short vision, as their food lies at their feet, and hence their eyes are singularly convex.

1306. Amongst the predaceous beetles, longer vision is required, and the convexity of the compound eyes is greatly reduced.

1307. The Bees, on the other hand, need telescopic vision to guide them in their long flights in search of honey and wax; but, when engaged in the act of collecting, or in making, and hermetically sealing their beautiful cells, near vision becomes necessary, and hence much convexity of their compound eyes.

1308. The telescopic form of eye, when present, is in the form of two or three single, distinct eyes, of larger size than any of the facets of the compound eye, and placed in the best possible position for the exercise of their function—on the vertex (crown of the head). Caterpillars have only a variable number of these single eyes, grouped together, however, as a common mass, with but a moderate interval of space between them.

1309. Much disagreement prevails in regard to the true structure of the Insect eye, and of the three authorities who have chiefly examined it, no two of them hold the same opinion. These authorities are, Marcel de Serres, Straus-Durckheim, and J. Müller.

1310. According to Straus, the epidermis continues over the ex-

posed surface of the eye, as in serpents; it is colorless and transparent. Beneath this transparent external covering, are placed the transparent facets, or corneæ of the several minute compound eyes, and beneath this latter layer the conical, transparent lenses. To render the description plain, a figure (according to this authority) is given (Fig. 411).

FIG. 411.

Structure of the eye of Melolontha vulgaris, Straus.

a. Continuous layer of transparent hexagonal corneæ.
b. The conical transparent lenses.
c. The optic filaments, connected to the apices of the conical lenses.

FIG. 412.

Müller's views, eye of Libellula.

a. Transparent cornea.
b. Crystalline lens.
c. Conical lens.
d. The pigment.
e. The optic filament.

1311. The structure of the insect eye by Marcel de Serres, was subsequently superseded by the statements of Straus, but a truer history is given by J. Müller.

1312. He discards the "epidermic covering of the cornea" of Straus, which really has no existence.

1313. Beneath the cornea, Müller found a minute double-convex lens, possessing (like the crystalline lens of man and the higher animals) *two curves;* the flatter or shallower curve being placed in front, and the deeper curve behind.

1314. The bases of the conical lenses, according to Straus, are perfectly flat, but Müller found them to be convex, and that they touched the greater curve of the crystalline lens, only at the centre—the surrounding space being filled by the pigment.

1315. To illustrate this theory a figure is given (Fig. 412).

LESSON XCI.

THE EYE IN INSECTS, CONTINUED.

1316. Müller, however, has not exhausted all the facts in relation to the structure of this important organ of sense.

1317. Behind the horny substance of the transparent cornea, is a whitish membrane, divisible into laminæ, or layers, which contains the crystalline lenses; with moderate care it may be detached, re-

taining the lenses in situ. In some Insects this membrane is particularly delicate, and in these cases it is more likely to remain attached to the transparant cornea, showing the lenses, when viewed by transmitted light, in the centre of the facets, severally; this is shown from a preparation of the Flesh-fly (*Musca carnaria*), Fig. 413. A beautiful specimen of the membrane, detached, with the lenses, was obtained from a small Caterpillar of this country, name unknown; a figure of it is given (Fig. 414). In this specimen the lenses are of unusual size, the posterior surface being of great convexity.

Fig. 413.

Transparent cornea, with lenses in situ; M. carnaria.

Fig. 414.

Lamina of the transparent cornea, containing the lenses, Caterpillar.

1318. The conical bodies are usually colored, but very delicate in texture, and possessing a semi-transparency.

1319. They have generally a faint yellow color, and they become decomposed in a very short time in water; neither can they be preserved very well any how; in spirit they contract so much as not to be visible, and in other preserving fluids it is extremely difficult for the well-practised eye to detect them; hence they should be sought for in freshly caught insects.

Fig. 415.

Conical bodies, M. carnaria.
a. Cone.
b. Optic filament.

Fig. 416.

Cone of a Caterpillar.

1320. All authors agree in believing the conical lenses to represent the vitreous humor of the eyes of the higher animals, a fact confirmed by the difficulty of preserving them.

1321. They are undoubtedly convex at their large extremity, and in some insects (M. carnaria) remarkably so.

1322. The optic filaments are not attached to the terminal points or apices of the cones as represented by authors, but, on the contrary, pass entirely through their centre (*b*, Fig. 415), and are sometimes seen projecting through the large end (base of the cone). In Musca carnaria, examined by a fourth object-glass,

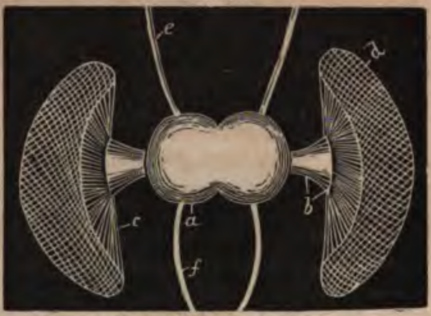
they appear to be of great size; they have consequently been reduced in the figure given of them (Fig. 416).

1323. In the perfectly fresh state in which they were seen, each optic filament formed a very beautiful sight, possessing, in every instance, an axis-cylinder; the white substance was too transparent to be visible.

1324. The cones of the Caterpillar, above referred to, are still larger (Fig. 416), and these have been preserved, fortunately, in a saline solution, but they are opaque, and, whether the nervous filament enters the cone or not, cannot now be determined; the bases of these cones are much flatter than those of Musca.

1325. The mode of connecting the several lenses of the compound eye of an Insect with the brain, is shown in a figure copied from a preparation of the brain of Blatta Americana (Fig. 417).

FIG. 417.



Brain, Blatta Americana.

a. The Cerebrum, or supra-œsophageal ganglion.
b. The optic nerves, terminating in the optic lobes.
c. Optic filaments, one of which is in connection with each individual eye.
d. Facetted external cornea.
e. Antenneal nerves.
f. Nerves connecting the brain with the first thoracic ganglion.

1326. The inferior portion of the brain, or infra-œsophageal ganglion, cannot be seen in this Insect, in viewing the brain from the upper surface, because it lies immediately below the supra-œsophageal ganglion, and, being much smaller, is concealed by it, and can only be seen from the under surface.

1327. There is one fact in connection with the compound eyes of Musca carnaria, that has escaped the observation of the authorities, namely, that all the important elements of a visual organ rest upon and are supported by an aggregated arrangement of fat lobules, of exquisite beauty, and, as might be expected, existing in a state of the most perfect analysis. A figure of these lobules is given (Fig. 418).

FIG. 418.

Fat lobules of the eye, M. carnaria.

1328. When the plan of connection of the compound, or facetted eye, with the brain is considered, it is not difficult to understand its action; each individual organ transmits to the optic lobe a picture of what it sees, and

the combination of a vast number of detached portions of even a large picture makes upon the optic lobe a perfect and undivided whole, the impression of which is conveyed to the brain by the optic nerve, not as a divided, but as a single picture. An Insect, therefore, has no business to know from any practical results that it possesses more than a single eye on each side of its head.

1329. The necessity for such a vast number of distinct organs of vision, is a consequence of their fixity of position; it is essential for their well being, to guard and protect themselves from their numerous enemies, ever ready to destroy them, that they possess vision in every conceivable direction, and the predaceous varieties require a no less perfect development of the organ to enable them to discern their nimble prey. The large extent of surface occupied by the compound eyes, fully effects this desirable object; above, below, before, behind and laterally, asleep or awake, are an infinite number of vigilant guardians, never closed nor veiled by eyelids, but ever on the alert and ready to give the alarm.

1330. The number of distinct organs in the facetted eye has been computed (by the aid of a micrometer), by those persons curious in such matters, thus: the House-fly possesses 4,000; Libellula (Dragon-fly), 12,554; Papilio, 17,355; Cossus ligniperda, 11,300; Mordella (a small beetle), 25,088.

1331. Hairs are frequently found connected with the compound eyes; they are placed in the depressions between the corneæ, and afford protection (like eyelashes) to the organs.

1332. Bees have to enter the expanded cup of flowers, in search of the nectar; their eyes might suffer abrasion and become opaque from the frequent contact with the petals, or they might be obscured and rendered useless by aggregated pollen masses. But no such contingencies can occur to them, in consequence of the protection afforded by their eyelashes.

1333. The telescopic, or simple eyes, are differently constructed. Usually, these are of great size, as compared with any of the facets of the compound eye.

1334. Immediately behind the hemispherical, convex, transparent cornea, is a well-shaped, double-convex, crystalline lens. Like those already described, it possesses two curves, the deeper one being behind. This latter surface fits accurately into a vitreous humor, the posterior portion of which is rounded, and is received into a bowl-shaped expansion of the optic nerve—a true retina; in addition, there is a choroid coat, and a pigmentary layer, so that all

the elements are here found of a well-developed visual organ. A distinct optic nerve is given to each simple eye, which at once transmits to the brain the image formed upon the retina.

LESSON XCII.

THE EYE OF INSECTS, CONCLUDED.

1335. To show the connection of the optic nerves of the single eyes with the brain, a figure, copied from a preparation of the brain of Mantis religiosa, is given (Fig. 419). The large, well-formed

FIG. 419.

Brain, Mantis religiosa.

cerebrum is shown at *a*; posterior to which, at some distance, the cerebellum (*b*), is seen; the crura, which connect the two hemispheres, are marked *c, c*; the optic nerve of the compound eye is shown at *d*; the optic lobe is marked *e*; the optic filaments, which spring from the optic lobe, are shown at *f*; the nerves distributed to the antennæ at *h*; the optic nerves of the simple eyes at *i, i*; and the bowl-shaped retinal expansion of optic nerves of the simple eyes at *k*.

1336. From the mathematical figure of its several component parts, the transparent cornea is an important part of the optical apparatus. Authors have not agreed with regard to its figure; some claim it to be plano-convex, the plane surface within; others assert that it is double-convex; whilst the truth appears to be that it is neither, but, like the human transparent cornea, it is a *meniscus* (from the Greek, signifying *a little moon*); in other words, it is convex on its outer surface, and concave within.

1337. The crystalline lenses fit into the concave surfaces of the cornea, but how accurately is not known, nor whether a space is reserved for an aqueous humor—these, at present, are matters of conjecture.

1338. From the fact that the pigment, which limits the aperture of the lens by coating its sides, from the circumference towards the centre, and thus forms *an iris*, there is great probability of the presence of an aqueous humor.

1339. If a carpenter had to fill a given space with boxes of uniform size, he must adopt one of three mathematical figures: they must be either square, triangular, or hexagonal—the first and last are used in the formation of the corneæ of insects.

1340. The eyes in the centre of the facetted organ are always the largest, and most perfect hexagons in form. As they approach the margins, they begin to assume *a square form*, which, at the extreme edge, is perfected; so that both these figures exist in the same

FIG. 420.

Centre of the transparent cornea, M. carnaria.

FIG. 421.

Transparent cornea, towards the edge, M. carnaria.

FIG. 422.

Transparent cornea, at the edge, M. carnaria.

eye, chiefly, it would appear, for the economy of space. This is well shown in the transparent cornea of Musca carnaria (Fig. 420); first we see the perfect hexagons in the centre of the cornea; secondly (Fig. 421), the gradual change to a square form; the process of change is still further continued, till at last a series of perfectly square cells are formed (Fig. 422).

1341. In the cornea of a Beetle a similar arrangement occurs, but the square cells are not so sharply formed; so, too, in the Dragon-fly, although in this insect the hexagons glide into parallelograms rather than squares, the like arrangement generally prevails; but there are exceptions.

1342. Such may be the structure of the eye in some insects, but some important differences, not yet recorded, occur in the eyes of other insects. A large Beetle, *Prionus longimanus* (its specific name signifying "long arms," and applied to the great length of the first pair of legs), commonly known as the "Harlequin-beetle," from the many colors it possesses, and the peculiarity of their arrange-

ment, has compound eyes of unusual size, and which offer great facilities for studying the structure of the transparent cornea, and especially of the lenses.

1343. It has been already remarked that the cornea is lined with a membrane, to the posterior portion of which the crystalline lenses are attached, and removing this from the cornea of Prionus, and submitting it to the microscope, an interesting scene presents itself.

1344. The lines which separate the corneæ severally, are strongly marked; the cells are, generally, perfectly round, although those towards the margins are oval, and quite flat; these cells are so many open holes (Fig. 423), as if to admit the anterior portion of the true crystalline lens; moreover, being smaller, they act *as stops* to a structure yet to be described.

1345. If we now examine the cornea from which this membrane has been detached, a very remarkable sight meets us.

1346. The cells, or the transparent spaces of the cornea, are filled with a series of crystalline prisms, which stand up far above the level of the membrane in which they are situated; some of them are round, others

FIG. 423.

Posterior layer of the transparent cornea, P. longimanus.

FIG. 424.

Prismatic lenses in situ, Prionus longimanus.

oval; hexagons (six sides), pentagons (five sides), cubes, and even triangles, are all represented in one or other of these prisms (Fig. 424). They appear to be so firmly impacted in the cells, that it is only reasonable to suppose that they fit it accurately; in this case the anterior portion must be convex, fitting the concave inner surface of the cornea. The terminal portions now presented to the spectator, and which were applied to the round holes of the membrane removed, are perfectly flat, but much larger than the round holes, which, as before remarked, act as stops. This would give a series of plano-convex lenticular bodies, sealed up, as it were, in the sub-

stance of the transparent cornea—a structure that may (and doubtless does) prevail to some extent in insects, and justify the peculiar figure of the cornea of the Melolontha vulgaris, given by Straus-Durckheim, and of Libellula by Müller.

1347. These prismatic, or lenticular bodies, are wider at their anterior than at the posterior extremity; they possess precisely the appearance that a human crystalline lens, preserved in alcohol, presents—they transmit light, but have lost the power of defining objects; at best, they now possess but semi-transparency.

1348. It must be understood that this arrangement of lenses (very like a Stanhope lens), in the transparent cornea, is in addition to the double-convex lens, vitreous humor, &c., neither of which were preserved in the beetle in question; it had once been in spirit, but had become dry long prior to dissection.

1349. At the margins of the cornea, the lenses have in some instances fallen out, and display the entire depth of it admirably. The horny transparent portion is thin, but the partitions between the transparent portions have great substance, thus leaving deep cells for the reception of the lenticular, prismatic bodies.

1350. Probably a transverse section of this cornea, undissected, would have presented a figure very similar to that of Straus and Müller, both of whom agree in making this portion of the compound eye of insects of great depth.

1351. They only differ in one respect, as regards this tissue: Straus says it is plano-convex; Müller, that it is double-convex.

FIG. 425.

Section of the eye of Prionus longimanus.

1352. These preparations, therefore, demonstrate that the horny layer which forms the transparent cornea is concavo-convex; instead of being of great depth, as represented, it is a *thin layer;* that the interspaces between the facets of this tissue descend, to a considerable space, in the posterior direction, thereby leaving long and deep cells for the reception of the plano-convex prismatic crystalline bodies; that these are shut in by a layer filled with round holes, smaller than the plane surface of these prisms; that the anterior part of the true crystalline lens passes through these round holes, the large margins of which cut off the light, and form a kind of iris; and that the posterior portion of the last mentioned lenses, with their deeper curve, touch the

convex part of the conical vitreous humor, the space around the point of contact being filled with pigmentary matter.

1353. This is illustrated by Fig. 425. The convex portion of the transparent cornea is shown at *a*; the concave surface of it at *b*; the descending walls of the cornea at *c*; the prismatic bodies, that are included in its substance, at *d*; the posterior layer, which encloses the prisms, at *e*; the crystalline lens is shown at *f*; its posterior portion, in apposition with the conical vitreous humor, at *g*; and the conical vitreous humor, *h*.

LESSON XCIII.

THE EYE IN ARACHNIDA, MOLLUSCA, AND FISHES.

1354. In the Arachnida, the simple eyes are the largest and most perfect forms of ocelli met with in the articulated classes. In the Spiders they are generally eight in number, arranged symmetrically in one or two transverse rows on the upper and forepart of the cephalo-thorax. The largest forms of these organs are met with in the Scorpions, in which they have been the most frequently examined.

1355. Beneath the transparent cornea, in the eye of the Scorpion, there is a spherical, firm, transparent lens; beneath this, a vitreous humor, which fills half of the eyeball, surrounded by the pigmentum and the choroid, excepting on the forepart, where it bounds the pupil like an iris, and on the back part, where it is penetrated by the optic nerve. The optic nerve expands into a well-formed retina, investing all the convex posterior portion of the vitreous humor.

1356. Organs of vision are not required, neither are they developed in the fixed or slow-moving Molluscous animals; and in those individuals of this class which possess them, they are not aggregated together like those of the Worms, the Myriopods, or the Arachnida, neither are they compound organs, like the eyes of the Crustacea and Insects.

1357. In the Gasteropods the eyes are always two in number, movable, and generally pedunculated—frequently found at the summit of one pair of tentacles, as in the Slug and the Snail. Some of the naked Gasteropods, as the Eolis (Fig. 263), the Doris, and

others, appear to be destitute of eyes; in the naked Aplysia they are but minute black dots.

1358. In some of the Gasteropods (Harpa elongata, Fig. 381) the eyes are placed on tubercles, at the bases, or near the bases of the tentacles. Such is the arrangement in the beautiful *Cyprea tigris* from the South Seas (Fig. 426).

1359. In this animal the two long tentacula (*a*, *a*) present, near

FIG. 426.

Cyprea Tigris, or Leopard Cowry.

their bases, two prominent, round, black, and movable eyes (*c*, *c*), with smooth, transparent, glistening corneæ. The tentacula being placed above the mouth (*b*) and in front of the syphon (*d*), the eyes, which are raised on tubercles at some distance from the base of the long, slender tentacula, have a considerable range of vision. Above the expanded foot (*g*, *g*) is seen the inner surface of the mantle (*e*), turned up over a portion of the shell (*h*), and covered with small ramified tentacular extensions (*f*), which warn the animal of danger from behind.

1360. In the *Carinaria Mediterranea* the optic nerves are seen passing directly to the eyes from the cerebral ring (Fig 380, *i*).

1361. In the general plan of their formation, the eyes of the Molluscous animals form a near approach to the ordinary condition of these organs in Fishes, and the higher vertebrated classes.

1362. In all the vertebrata the eyes are two in number, and symmetrically disposed on the sides of the head, and the differences which they present relate chiefly to the density of the media through which the various animals receive the rays of light, and the extent of development of the external protecting parts of these delicate organs.

1363. From the imperfect development of the nervous system in Fishes, and the obscurity of the element through which they move, their organs of vision are of great size, and, from the density of the

watery medium around them, they have little necessity for an aqueous humor, and their cornea is flat. To preserve this flatness in front, the sclerotic coat is thickened and consolidated; and it is also to prevent its assuming the spherical form in Birds, by the equal pressure of the contained fluids, that the sclerotic is there strengthened with bony plates, which preserve the tubular form of the eye, and the great convexity of the cornea in that class.

1364. The crystalline lens in Fishes is composed of minute transparent fibres, disposed in concentric layers, and united by their serrated edges, as seen in the Codfish (Fig. 427), the layers increasing in density from the surface to the centre of the lens.

FIG. 427.

Fibres of the crystalline lens, Codfish.

1365. The organs of vision are smallest in such Fishes as burrow in the mud and sand; they are larger in predaceous Fishes, which frequent the dark depths of the ocean, than in those which reside on the shallow coasts, or in fresh waters. Ciliary processes are rarely developed in this class.

LESSON XCIV.

ORGANS OF VISION IN THE HIGHER ANIMALS

1366. As the eyes, we must henceforth consider, possess a more complicated structure than the organs hitherto examined, it appears to be desirable to give a brief enumeration of the parts which collectively form a visual organ in the higher animals.

1367. The globe of the eye is composed of *tunics* and *humors*. The tunics are three in number, the

1. Sclerotic and cornea.
2. Choroid, iris, and ciliary processes.
3. Retina, and zonula ciliaris.

1368. The sclerotic (*skleros*, hard) and cornea form the external tunic of the eye-ball, and give to it its peculiar form. The sclerotic is much thicker behind than before; it is pierced at its posterior surface by the optic nerve, ciliary nerves, and arteries. The cornea is attached to its anterior part, by means of a bevelled edge; its anterior surface is also covered by a thin tendinous layer, the *tunica albuginea* (white tunic), which is covered for a part of its extent by the mucous membrane of the front of the eye, the *conjunctive* mem-

brane, or conjunctiva: such is the brilliancy of its whiteness at this part, that it is commonly called "the white of the eye." The conjunctiva (human) is a tissue of great vascularity, and a figure of it, copied from a preparation, is given (Fig. 428). The portion of the preparation selected for illustration, is where the membrane approaches the margin of the upper eye-lid; in this situation (seen at the lower part of the figure) the capillaries are very minute, and densely aggregated—the general surface of the membrane (of both lids) is covered by arteries, veins, and loosely scattered capillaries, such as form the greater part of the figure. The Conjunctiva still lines the upper and lower eye-lids, upon which it is displayed; and so dense and minute is the arrangement of the capillary plexuses along the line of the lids, that, to unassisted vision, they appear to consist of simple lines of intense redness.

FIG. 428.

Conjunctiva injected, human.

1369. The *choroid* is a vascular membrane of a rich chocolate brown color upon its external surface, and of a deep black color within. Externally it is connected to the sclerotic coat, internally to the retina. It is pierced posteriorly for the passage of the optic nerve, and anteriorly it is connected with the iris, ciliary processes, and junction of the cornea and sclerotic, by a dense white structure, the *ciliary ligament*, which surrounds the circumference of the iris like a ring.

1370. This membrane is composed of three layers:—1. An external or *venous* layer, which consists of veins arranged in a peculiar manner, called *venæ vorticosæ*. 2. Middle, or arterial layer, is formed by the ramifications of minute arteries, and secretes upon its surface the *pigmentum nigrum*. 3. The internal layer presents a beautiful appearance under the microscope; it is composed of several laminæ of hexagonal cells, which contain the granules of pigmentum nigrum (black paint).

1371. In animals the pigmentum nigrum is replaced by a layer of considerable extent, and of metallic brilliancy, called the tapetum.

1372. The *iris* (a rainbow) is so called from its variety of color in different individuals; it forms a curtain or septum (partition) between the anterior and posterior chambers of the eye, and is pierced in its centre by a circular opening, called the pupil.

1373. The *ciliary processes* consist of a number of highly vascu-

lar, triangular folds, formed (apparently) by the plaiting of the internal layer of the choroid. They are about sixty in number (in man), and may be divided into large and small, the latter being situated in the spaces between the former. These processes are covered by a thick layer of pigmentum nigrum.

1374. The *retina* is the expanded portion of the optic nerve, and is the medium, equivalent to the ground glass of the Camera obscura, upon which all images seen by the eye are painted. Notwithstanding its extreme delicacy, it consists of *three layers;* these are, the external, or Jacob's membrane; middle, or nervous membrane; internal, or vascular membrane.

1375. The *zonula ciliaris* is a thin vascular layer, which connects the anterior margin of the retina with the circumference of the lens. It presents upon its surface a number of small folds corresponding with the ciliary processes, between which they are received.

1376. The HUMORS of the eye are also three; these are, the aqueous humor, situated in the anterior and posterior chambers of the eye.

1377. The *anterior chamber* is the space between the cornea in front, and the iris and pupil behind.

1378. The *posterior chamber* is the narrow space bounded by the posterior surface of the iris and pupil in front, and by the ciliary processes and lens behind.

1379. The *crystalline humor*, or lens, is situated behind the pupil, and is surrounded by the ciliary processes, which slightly overlap its margin. It is more convex on the posterior than on the anterior surface, and is embedded in the anterior part of the vitreous humor, from which it is separated by the hyaloid membrane. It is invested by a proper capsule, which contains a small quantity of fluid, and is retained in its place by the attachment of the zonula ciliaris. In its ultimate structure the crystalline lens consists of a multitude of fibres, the edges of which are wavy, or undulate (Fig. 429). In other animals they are serrated, and by this means lock into each other, and form a tissue. This can be seen, in the higher animals, in the fibres of the Ox (Fig. 430).

FIG. 429.

Fibres of the crystalline lens, human.

FIG. 430.

Fibres of the crystalline lens, Ox.

1380. The *vitreous humor* forms the principal bulk of the globe of the eye. It is enclosed in a delicate membrane, the *hyaloid*,

which sends processes into its interior, forming cells in which the humor is retained. A small artery may sometimes be traced through the centre of the vitreous humor to the capsule of the lens.

1381. The *sclerotic coat* is a tunic of protection, and the cornea a medium for the transmission of light. The choroid supports the vessels destined for the nourishment of the eye, and by its pigmentum nigrum absorbs all loose and scattered rays that might confuse the image impressed upon the retina. The iris, by means of its powers of expansion and contraction, regulates the quantity of light admitted through the pupil.

1382. The *transparent cornea*, and the humors of the eye, have for their office the refraction of the rays in such proportions as to direct the image in the most favorable manner upon the retina.

1383. Such, then, are the several parts, and such their uses in the eyes of the higher animals, and it only now remains to point out the peculiarities of structure which distinguish classes, or the individual members of classes in the ascending scale of being.

LESSON XCV.

THE EYES IN REPTILES, BIRDS, AND MAMMALIA.

1384. The eyes of Reptiles are more fitted to receive the rays of light from the rare medium of the atmosphere than those of fishes; their cornea is generally more convex, their aqueous and vitreous humors more abundant, and their lens less spherical in form; they also possess two movable eyelids, and a membrana nictitans (a thin membrane, drawn rapidly across the front of the eye, by which its surface is wiped, and obstructions removed; the exercise of this organ is said to simulate winking).

1385. In many of the Crocodilian reptiles, and the Tortoises and Turtles, the sclerotic, at its anterior part, supports a circle of osseous plates, which surround the transparent cornea, as in birds (Fig. 431). These plates around the cornea existed in the *Ichthyosaurus*, and are found abundantly in the fossilized condition.

1386. In the eye of a Tortoise (*Emys Europœa*, Fig. 432) the cornea (*a*) is pretty convex, from the abundance of aqueous humor (*b*) in the anterior chamber, and the margin of the cornea is supported by ten osseous plates (Fig. 431), imbricated like those of birds, and placed in the anterior part of the sclerotic (*d*, *d*), near to the ciliary processes (*f*), and to the fixed margin of the iris (*e*).

The crystalline lens (g) has a compressed elliptical form, and a smaller axis than the vitreous humor (h). The retina terminates with a thickened edge at the beginning of the ciliary processes, and a similar structure is presented in most of the Chelonian reptiles.

Fig. 431.

Bony plates of the eye in Reptiles and Birds.

Fig. 432.

Eye of Emys Europœa.

1387. In the Snapping Turtle, the middle coat of the choroid presents a magnificent spectacle, when its vessels have been minutely injected, a figure of which is given (Fig. 433), copied from a preparation.

1388. The posterior part of the choroid, it will be seen, is pierced for the transmission of the optic nerve (a); it is called the *foramen of Soemmering.*

1389. It will be seen that the vessels at this part are very minute, and that they gradually and steadily increase in size to the anterior portion, just below the ciliary processes. At this point they assume a very beautiful arrangement, and one that is peculiar, as compared with other choroids.

Fig. 433.

Choroid coat of the eye, Snapping Turtle.

Fig. 434.

Ciliary processes, Snapping Turtle.

1390. The ciliary processes are also well developed in this Turtle (Fig. 434); they are, however, remarkable for their shortness and thickness, as compared with the same organs in other animals. The lower part of this preparation joins the upper part of 433.

1391. In Birds the round pupil is capable of great and rapid changes of dimension, aided by the remarkable mobility of the iris. This highly movable and bright colored iris, with its black uvea (the posterior coat of the iris), appears sometimes detached from the free anterior margin of the choroid, and its colored surface presents aggregations of minute globules, like those of the choroidal pigment.

1392. Birds possess a *membrana nictitans*, very perfect upper and lower eye-lids, which are provided with tarsal cartilages and Meibomian glands, and even eye-lashes, in addition to the necessary muscles for their elevation and depression.

1393. The eyes are large in most of the Herbivorous mammalia, especially the ruminantia, the rodentia, and most of the pachydermata (thick-skinned animals), and also in most of the nocturnal species. They are very small, even in the adult state, in the burrowing animals, as Moles, Shrews, &c.

1394. The same circumstances which modify the form of the eye, and the proportions of its refractive parts in other classes and animals, affect the organ in this; thus in the visual organ of swimming mammalia, there are many affinities with the eyes of fishes; those of bats approach those of birds; and intermediate forms are allied to the eyes of reptiles.

1395. In Cetaceous animals, which constantly reside in water, and receive the rays of light through that dense refractive medium, the eyes have little aqueous humor, the cornea is flat, the crystalline lens is large, dense, and spherical, and the vitreous humor is less abundant than in terrestrial quadrupeds; and in order to preserve this flatness of the forepart of the eye, the sclerotic coat, like that of fishes, is thick, firm, and elastic, especially over the back and the anterior parts of the eye. The sclerotic is an inch thick at the back and the anterior parts of the eye in the Whale.

1396. The large eye of the ruminantia, and of most other herbivorous quadrupeds, often presents a greater lateral than vertical direction of the transparent cornea, the pupil, and even of the entire eye-ball, by which the lateral range of vision is extended in these timid and watchful animals, during the inclined position of the head.

1397. The visual requirements of these animals are peculiar;

when the head is bowed down to the ground, and the creatures are occupied in cropping the herbage, microscopic vision is required; but when seeking the best pastures, or keeping a watchful look-out for fear of surprises from their natural enemies, the feline species, telescopic vision is essential. For this purpose they possess a *seventh muscle* to the eye-ball—one more than belongs to other animals—this is called the retractor muscle, and its office is to draw the eye-ball back into the orbit, thereby effecting great alteration in its focal capabilities. The eyes of a dead Cow, or Sheep, are generally retracted deep into the orbit, by the contraction of these muscles. This muscle may be fitly compared to the coarse adjusting screw of a microscope; the fine adjustment has yet to be explained.

1398. While the muscles of the eye in all animals contribute, by their action, in altering the focal length of the eye, the last act, by which thorough sharpness of definition is acquired, is reserved for *the ciliary processes.* It has been stated that these bodies impinge upon the crystalline lens, at its margins; in addition to being highly vascular, they are also provided with erectile tissues, and when the capillaries are distended with blood, the processes become erect. In this condition their combined action slightly moves the lens, by which means the last process of perfect adjustment prevails, and is made complete.

FIG. 435.

Ciliary processes, Ox.

1399. The ciliary processes of the ruminant are without parallel in the animal kingdom; they consist, even in the injected state, of a vast number of folds (Fig. 435), and when straightened out by the action of the erectile tissue, they must exercise an unusual influence on the position of the lens.

LESSON XCVI.

THE EYES IN MAMMALIA AND MAN, CONTINUED.

1400. In the Feline animals, the ciliary processes are beautifully developed, and more nearly resemble those of Man.

1401. In the domestic Cat (Fig. 436), they consist of a number

of plates, of great breadth at their anterior portion; the vessels at the posterior portion gradually glide into the vessels (arteries) of the middle layer of the choroid.

1402. The veins (venæ vorticosæ) of the external membrane of the choroid, are well seen in a preparation of them from the Dog (Fig. 437). Some of them are of large size, and all of them (in the preparation) distinguished by great roundness.

1403. But it is in the visual apparatus of Man, organized for seeing in the erect position of the trunk, that we find the most complete protection of the orbits, by solid osseous parietes, and the most parallel direction of their axes. Shaded externally by the eye-

FIG. 436.

Ciliary processes, eye of the Cat.

FIG. 437.

Venæ vorticosæ, choroid of Dog.

brows, which are moved by their proper muscles, and protected by two highly movable eye-lids, which continue over the forepart of the organ, the human eye presents only a small rudiment of the third eye-lid, or membrana nictitans, so highly developed in most of the inferior vertebrata.

1404. The eye-balls are nearly spherical in form, with their axes parallel, and perforated behind by the optic nerves; they are supported on the back part by a large deposit of adipose substance (fat), and are moved by four recti (straight), and two oblique muscles.

1405. A longitudinal section of the human eye will be found at Fig. 438.

The function of the optic nerve is to inform the brain of all the details of form, color, &c., of any object pictured upon its thin expansion, the retina.

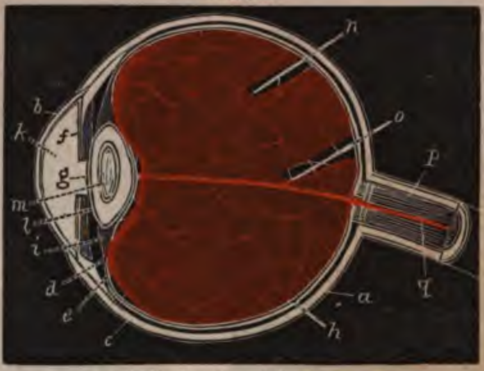
The tubes, or fibres, as they have been erroneously described, which enter into the composition of an optic nerve, decussate (di-

vide, intermingle) with the tubes of the other optic nerve. By this arrangement, an object seen by one eye has its history given, simultaneously, to that part of the brain with which the other optic nerve communicates, directly through its agency.

If one eye be closed, by the hand or a bandage, objects seen by the *open eye* are not sharp and distinct, because it has lost half its ordinary power.

In looking through Telescopes and Microscopes, it is most impor-

FIG. 438.



Longitudinal section of the human eye.

a. The sclerotic coat.
b. The cornea, connected to the former by means of a bevelled edge.
c. The choroid, connected anteriorly with
d. The ciliary ligament, and
e. The ciliary processes.
f. The iris.
g. The pupil.
h. The third layer of the eye, the retina.
i. The canal of Petit, which encircles the lens (*m*); the thin layer in front of this canal is the zonula ciliaris.
k. The anterior chamber of the eye, containing the aqueous humor.
l. The posterior chamber.
m. The lens, more convex behind than before, and enclosed in its capsule.
n. The vitreous humor, enclosed in the hyaloid membrane,
o. Tubular sheath of the hyaloid membrane, which serves for the passage of the artery of the capsule of the lens.
p. Neurilemma (sheath) of the optic nerve.
q. The arteria centralis retina, embedded in its centre.

tant to keep both eyes open, and this can easily be done by turning the head aside, and thus diverting the axis of vision. Those persons who shut one eye never see an object distinctly, and what is worse, they have created pain in both eyes; the open one has been strained to do impossibilities, and the closed eye intensely excited but not permitted to be active. If properly managed, the spectator will have a clear view of the object in the microscope, and distinctly see, at the same time, objects on the table, and at a wide angle.

1406. The ciliary processes may be seen in two ways, either

by removing the iris from its attachment to the ciliary ligament, when a front view of the processes will be obtained, or by making a transverse section through the globe of the eye, when they may be examined from behind, as in Fig. 439.

1407. In addition to the figure (slightly enlarged) displaying the arrangement of the full series of ciliary processes, a more highly magnified view of them, with their vessels injected, is given in Fig. 440.

1408. The vessels derived from the *arteria centralis retinæ*, and

FIG. 439.

Ciliary processes, human.

a. The divided edge of the three tunics, sclerotic, choroid, and retina.
b. The pupil.
c. The iris.
d. The ciliary processes.
e. The scalloped anterior border of the retina.
f. Choroid.

FIG. 440.

Ciliary processes, human.

distributed to the vascular membrane of the retina, form, when injected, an object of great interest; it is shown in Fig. 441.

1409. In the progress of development of the human organs of vision, during embryo life, the crystalline lens is found embedded between two highly vascular membranes; the one is the *anterior*, and the other the *posterior, capsule of the lens.* These membranes appear to attain their maximum (greatest) development at a certain given period, from which time the vessels begin to disappear by absorption, and at the time of birth are entirely removed.

1410. The capillaries of the anterior capsule (Fig. 442) are derived from the ciliary arteries, and form a beautiful series of loops divided into four somewhat triangular spaces, which collectively occupy the entire membrane, save the centre. In the process of absorption, the central portion is first removed, in each triangle, and

this process continues until four arched vessels alone remain attached to the inner circumference of the membrane, and finally these disappear.

1411. This membrane is sometimes (at a certain age) found attached to the crystalline lens, and sometimes it is detached; when

FIG. 441.

Vessels of the arteria centralis retina, human.

FIG. 442.

Anterior capsule of the lens, human.

the latter occurs, it has been usual to call it "membrana pupillaris" —it is in reality the anterior capsule of the lens.

1412. The posterior capsule lies between the crystalline lens and the vitreous humor. To perform its function, it requires to be vascular, but from the peculiarity of its position it appears to be cut off from all sources of supply.

1413. The arteria centralis retina passes through the vitreous humor, and having reached the posterior capsule, terminates in a plexus of capillaries distributed to that membrane, but which are not nearly so numerous as those of the anterior capsule; they are represented in Fig. 443; *a* is the terminal portion of the arteria centralis retina.

FIG. 443.

Posterior capsule of the lens.

1414. The vessels of the posterior, like those of the anterior capsule, are removed by absorption when their function has ceased, and the lens fully formed; it sometimes, but rarely, happens that they become permanent, and

when this occurs they produce a form of blindness for which there is no remedy.

1415. Amongst other tissues which enter into the composition of the eye-lids, are two thin lamellæ of fibro-cartilage, called *the tarsal cartilages*, which give form and support to the eye-lids.

1416. Between these cartilages, and embedded in them, lie the *Meibomian-glands*, so called from Meibomius, their discoverer. They consist of a long duct, which opens upon the edge of the eye-lids, surrounded by a cluster of follicles, which conceal the tube, except at its terminal portion. As these glands extend the whole width of the cartilages, they are necessarily longer in the upper than the under eye-lid; they differ in number in the two lids, there being twenty-four in the upper and thirteen in the lower lid.

1417. These glands secrete a fatty matter, and may be regarded as a form of sebaceous glands. Their chief function appears to be to keep the margins of the eye-lids soft (greasy), and prevent adhesion. They can at all times be well seen upon the inner surface of the lids, shining and glistening like so many rows of pearls (Fig. 444). In

FIG. 444.

Meibomian glands, in situ.

composition they consist of a lengthened tube, or duct, which extends from one end of the gland to the other. On either side a number of small follicles are found, so densely clustered as to entirely conceal the duct, except at its termination. The tarsal cartilages are grooved for the reception of these glands, which are retained in their place by a layer of cartilage, which folds over each gland, and another similar layer, which folds over the former. By lifting up these two folds, a gland can be easily lifted out of the groove in the lower cartilage, not being in any way attached to it. An enlarged figure of a gland, so obtained, is shown in Fig. 445; when magnified,

each gland is seen to consist of a basement membrane (*a*), and an epithelium (*b*) containing sebaceous matter; *c* represents the orifice of the duct. These glands are subject to disease, especially in children, which appears to partake of a congested character; the secretion is suspended, and the ducts closed up; in this form of disease the margins of the lids become inflamed, and the loss of the eye-lashes invariably follows.

FIG. 445.

Meibomian gland, removed and magnified.

1418. Thus we have seen these complicated optical instruments, the most universal in their distribution in the animal kingdom, and by far the noblest organs of sense, gradually advancing to perfection, from the animals of lowly organization, in which we first found them, up to man, where all their internal essential parts, and their external accessory apparatus, are the most exquisitely finished, and most minutely adjusted. It is chiefly through their means that he is connected to the external world, that he is enabled to provide for his wants, to acquire the materials of thought, to enjoy the sublime spectacle of the starry Heavens, and to gaze with fervent admiration upon the wonders and beauties of ever changing Nature, as revealed to him in this magnificent World!

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